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THE

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THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. I.—*The Submarine Great Canyon of the Hudson River;* by J. W. SPENCER, A.M., Ph.D.*

CONTENTS:

An Account of what has been done before this date.
The Hudsonian Canyon.
Surface Channels of the Continental shelf, and the Deep one of the Connecticut.
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The Magnitude and the Time of the Great Elevation.
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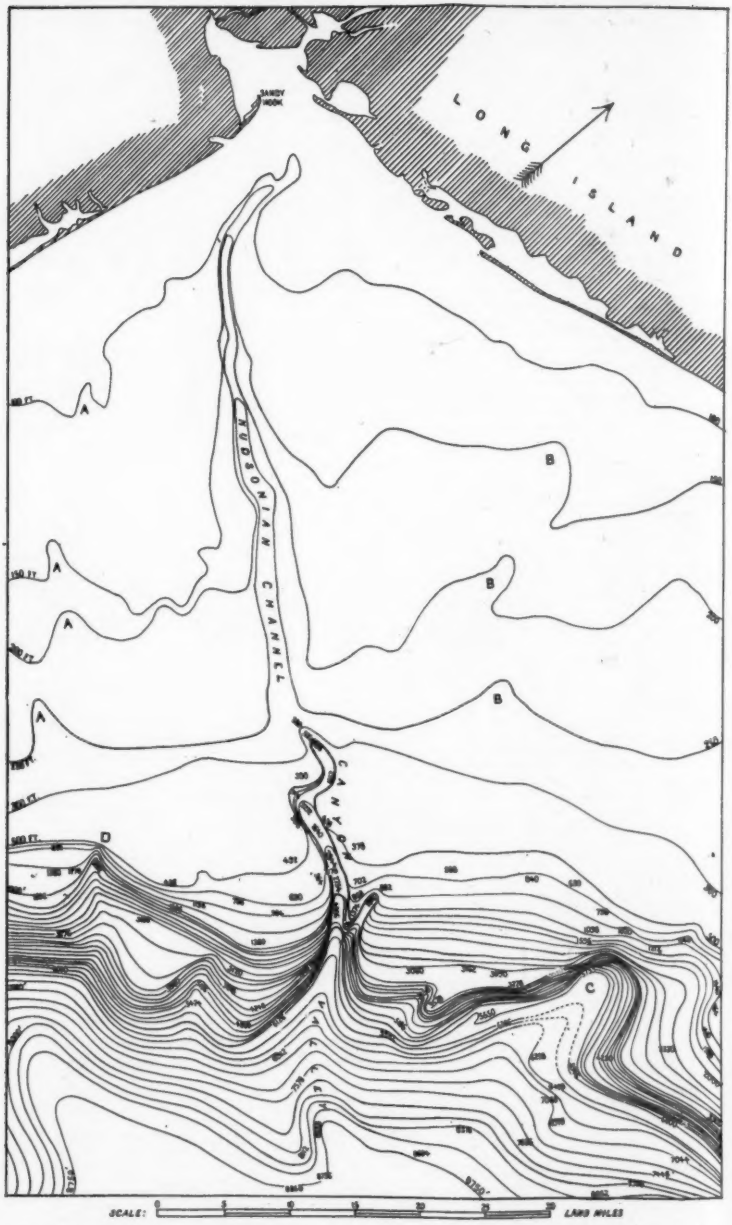
### *An Account of what has been done before this date.*

The early work of the Coast Survey brought to light a depression extending from near New York to the border of the Continental shelf. Prof. J. D. Dana was the first to recognize this feature as the submerged channel of the Hudson River, formed when the continent stood at a greater altitude above the sea than it does now. So much importance did he attach to it, as evidence of terrestrial oscillations, that a map of it appeared in all the editions of his Manual of Geology, since 1863, but only in the latest edition (1895) was it shown to reach to a greater depth than 720 feet. In the last revision the upper channel and the canyon sections are distinguished, the latter to a depth of over 2000 feet. But the discovery of the canyon was first announced by Prof. A. Lindenkohl in 1885† and further discussed in 1891.‡ He found that it reached to a depth of 2844 feet where the adjacent continental shelf was submerged to only 420 feet—a gorge of 2400 feet in

* This paper will simultaneously appear in the Geographical Journal of London.

† This Journal (3), vol. xxix, pp. 475–480, 1885.

‡ Ib., vol. xli, pp. 489–499, 1891.




Map of the Submarine Great Canyon of the Hudson River (by J. W. Spencer).

Soundings in feet. Isobathic lines 250 feet apart, from that of 500 feet to 8,750 feet. Very numerous soundings on continental shelf to 500 feet where the isobaths are 50 feet apart. A A A A and B B B show course of streams during a late Pleistocene elevation of 250 feet. C is position of the Connecticut canyon or valley, west of which are blank spaces in which the corrected soundings should be 1,896 and 2,340 feet.

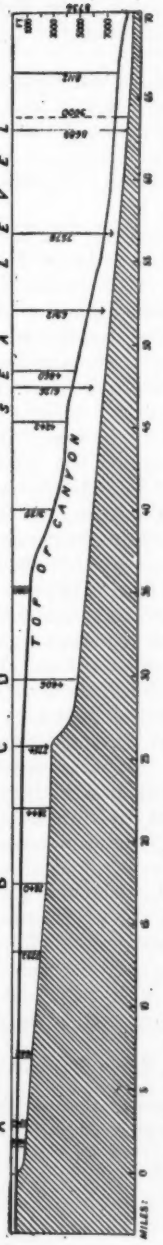



FIGURE 1.—Longitudinal section of Submarine Great Canyon of the Hudson River. At points where depths end in arrows the soundings were not taken in center but on side of the valley. A, E, B, C, D, location of cross sections. E is situated 4 miles above B. Soundings given in feet.
Since going to press, from additional information, abrupt steps of 400 and 500 feet respectively are found to occur in the gradient just above depths of 1662 and 2292-foot soundings.

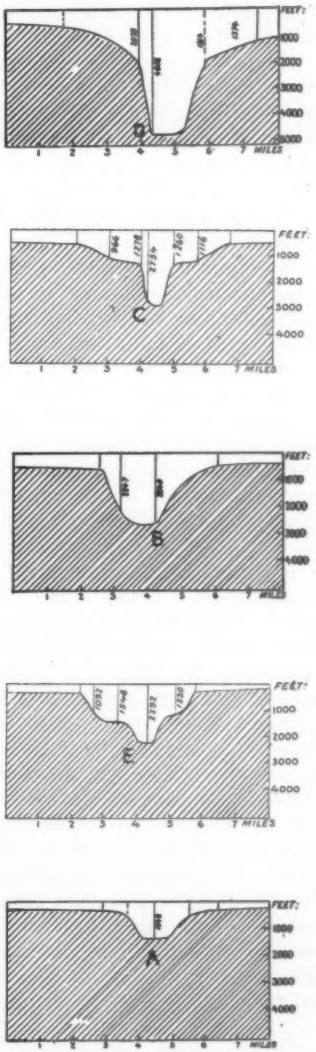



FIGURE 2.—Cross sections located at A, E, B, C, D, in longitudinal sections. Their position on map corresponds to similar depths, in feet, there shown. E (at a point 4 miles above B) and C show the double character of the canyon.

depth. From the soundings beyond the deep point, he at first thought a bar of 1600 feet in height crossed the mouth of the canyon.

In 1889, I pointed out that this canyon, along with those at the mouth of the Gulf of St. Lawrence and of the Maine, could be taken as yardsticks in measuring the late continental elevation to the extent of 3000–3600 feet. This was in the second paper published by the Geological Society of America, the first being by Prof. Dana.*

A few months later Dr. Warren Upham cited the Hudson canyon among the evidence he brought together to show that elevation was the cause of the glacial period.† In it he attributed the apparent bar to the action of coastwise wave-wash during the subsidence of the continent after the formation of the gorge. Though this bar was a large order for wave action, it was the only reasonable explanation of the deep hole if such it were, as suggested by the Coast Survey chart.

Again in 1890, Prof. Dana published a paper,‡ in which he says that the channel "affords strong evidence of the river origin and therefore the whole channel up to New York was once the course of the Hudson." In the last edition of his Manual he further says (page 948) that the former emergence of the continental border now sunken is proved by the Hudson submerged valley, citing also the cases of the canyons of the gulfs of St. Lawrence and Maine, mentioned above, as evidence of the elevation of the region in the glacial period to at least 3000 feet. It may be here stated that Prof. Dana, on seeing my account of the submarine valleys of the West Indian region, wrote to Prof. Lindenkohl, who replied that he was not aware of them, and hence the note in his Manual concerning them (page 949). Prof. Lindenkohl, however, later accepted my interpretation of the much deeper valleys§ which Dana doubted, confirmed by Prof. Lindenkohl's want of knowledge at the time, though Prof. Dana accepted my St. Lawrence canyon to 3600 feet below sea level.

In 1897 I read a paper before the British Association, stating that with the very insufficient soundings, the Hudsonian valley was recognizable to a depth of 12,000 feet,‖ illustrating how we may anticipate where canyons may be found. This paper, amplified into "The Submarine Valleys off the

* "The High Continental Elevation preceding the Pleistocene Period," Bull. Geol. Soc. Am., vol. i, pp. 65-70, 1890.

† Bull. Geol. Soc. Am., vol. i, p. 563. Also Geol. Mag. Lond. (3), vol. vii, p. 494, 1890.

‡ "Long Island Sound in the Quaternary era, with Observations on the Submarine Hudson River Channel," this Journal (3), vol. xl, p. 425, 1890.

§ Bull. Geol. Soc. Am., vol. xiv, p. 226, 1903.

‖ Ib., pp. 207–226.

American Coast," in 1902,* taking such phenomena as a whole, showed there was accumulative evidence suggesting that these submarine features were gauges for measuring the late great continental elevation.

The most recent discussion including that of the Hudsonian channel (1904) is in Dr. F. Nansen's epoch-making monograph on continental shelves and previous oscillations of shore lines,† reserved for later consideration.

### *The Hudsonian Canyon.*

The channel described by Lindenkohl begins about ten miles off Sandy Hook and extends for 93 miles before it plunges into the canyon. Land miles and not sea miles will be used throughout this paper. At its head, opposite Sandy Hook, the channel is buried by the sand of the coastwise drift-forming bars, though nearer New York it is much deeper. Lindenkohl had described the depth of the canyon to 2844 feet below sea level, with a bar in front, and no further information is shown on the U. S. Coast Survey charts. In revising my last mentioned paper, I found much additional data on the charts issued by the Hydrographic Office, greatly strengthening the evidence of the continuation of the Hudsonian valley, extending down the continental slope to great depths. But on the British charts I made a most astounding find of three soundings of 459, 801 and 229 fathoms. The position of the 459 and of the 801 soundings of the British chart so closely coincided with those of the Coast Survey chart‡ at 213 and 345 fathom points that they could not have been represented on the same charts. Thus the British chart showed no barrier to the canyon and very greatly increased the known depth of the narrow gorge, further defined by the 229 fathom point. The extraordinary depth would have been startling had it not been anticipated in all of my long series of analyses of submarine valleys. Both series of soundings were correct, the deeper ones having been made by Lt. Com. Z. L. Tanner§ in 1883 in the Fish Commission steamer Albatross. The older soundings had been retained on the Coast Survey charts.

The canyon of the Hudson River may now be extended and revised as follows: The mean edge of the continental border may be taken at a depth of 450–500 feet below sea level. The head of the canyon, in a direct line backward of the edge of

* Ib.

† "The Bathymetrical Features of the North Polar Seas, with a Discussion of the Continental Shelves and Previous Oscillations of Shore Lines," by Fridtjof Nansen. Quarto, pp. 1–232, plates 28. Published in English by the Fridtjof Nansen Fund for the Advancement of Science, Christiania, 1904.

‡ Coast Survey Chart, No. 8. B. A. Chart No. 2480.

§ Hydrographic Notice to Mariners, No. 56, 1883.

the shelf, is 20 miles, but its course is somewhat longer. The upper channel has a depth of 42 feet in the very level sandy plain, which is then submerged to only 288 feet (though a hundred miles from New York harbor). At this point there is an abrupt descent from the bed of the upper part to 1098 feet in the canyon, within the distance of about a mile. The gorge soon deepens to 1242 feet, where cross section A is taken.

The canyon extends nearly due east for six miles, where its depth reaches to 1662 feet. It then bends sharply at right angles to the south, and at 12 miles from its head a narrow inner gorge descends from 1770 to 2292 feet (in a distance of 1·5 miles) where the broad outer canyon attains a depth of only 1500 feet below sea level. Here the shelf is submerged about 250 feet, accordingly the outer and inner canyons have respective depths to 1250 and 2050. A cross section is shown in figure E (added since paper went to press) which is located near the soundings of 2292 feet shown on the map and longitudinal section. Here the canyon turns again at nearly right angles towards the east, though farther on it bends slightly southeastward. A depth of 2640 feet is reached in 18 miles, where cross section B is taken. At 23 miles the depth is 2844 feet, and at 26·5 miles is the position of the 213-fathom sounding, which was supposed to have indicated a bar, and close against which is the discovered sounding of 459 fathoms, as shown in the precipitous wall in cross section C. Nearly midway between these soundings is one of 457 fathoms (the last two not being situated quite in the center of the channel). These, with others on record, but not shown on the published charts, form a chain of soundings from one to two miles apart reaching to near the floor of the inner gorge, thus establishing its continuity. At this locality also, unpublished soundings further show the double canyon, the outer of which, with a breadth of four miles, is revealed to a depth of 1200–1300 feet below sea level, while the inner has a width not exceeding one mile but reaches to over 2800 feet. The gradients and depths of the canyon and their relation to sea level are shown in the longitudinal section figure 1. At 31 miles the 801 fathoms is found, close against that of 345 fathoms not shown on map. This last is on the side of the gorge, of 3800 feet, where the continental slope is further submerged 1000 feet. Here, too, is a great downward pitch in the gradient of 2000 feet in four miles. At this point the maximum breadth of the gorge, nearly 3800 feet above the floor of the canyon, does not exceed two miles, with the bottom necessarily narrower. Seemingly part of the slope of the wall where the deep sounding was found approaches 60 degrees. At 34 miles there is a short tributary from the north, heading in a typical

cove. Beyond this point, where the sounding is more than 4806 feet deep, the canyon feature must continue for several miles at least. I have carried it to the 42-mile point, where the continental shelf is submerged to 3000–3500 feet. At this depth we have several soundings which show that the 3000-foot isobath continues in a direct line as if across the canyon without any known suggestion that it sweeps round into the form of a broadened embayment. Its parallelism to the 500-foot line of the edge of the shelf shows the remarkable regularity of this zone of the great slope. There is also suggested the remains of a shelf or bench of depth corresponding to the Blake plateau south of Cape Hatteras.

Within a few miles the canyon appears to broaden out, and yet at 48 miles there is a steep cliff of 2000 feet or more on its southern side. Here the floor exceeds a submergence of 6126 feet, as the measurement is not in the center of the valley, nor have we obtained the sounding on the opposite northern edge, the last in the gorge being 4800 confined within walls of 3800 feet, though the walls are known on both sides lower down. Indeed this depth is still below that of the continental slope at 48 miles. Evidently the canyon section must reach to a depth of from 6000 to 7000 feet, which also corresponds to the deep valley of the Connecticut. (C on map.)

Beyond the canyon section is the southern side of the extended valley, demonstrated by a line of soundings, though not at its summit. The four soundings at about 8688 feet are specially important as proving the continuation of the Hudsonian valley. The first of these is at 63 miles. At 67 miles the lateral bank is at least 624 feet high (probably 1000 feet at least above the floor), and our record carries the valley to 71 miles from the head of the gorge. The end of this lower reach does not exceed 14 miles in width, but fuller soundings may limit it to 8 or 10 miles. Thus the valley is shown to exist to a depth of 9000 feet.

Beyond this point there are no soundings in the line of the valley, but lateral ones on both sides are suggestive, and at 100 miles east of this study, at a little less than 12,000 feet, is an embayment of 30 miles in breadth, with the depth of a few hundred feet. This cannot be a meaningless feature, though not part of the present analysis.

The breadth of the canyon hardly exceeds a mile at its head, but it soon widens to two miles or more. From the second turn (see map) a breadth of four miles is maintained for the outer canyon. The deeper inner gorge is reduced to a width of one mile or less, and is more sinuous than the outer. Beyond the tributary it is wider, five or six miles, though possibly more, as the next sounding is farther away, but a little

greater or less detail does not alter the general features, and the only important points left relate to the question of the canyon opening out into the valley and its depths, which the analysis shows is 6000–7000 feet, and farther on the characteristics are those of a valley rather than a canyon to 9000 feet below sea level.

*Surface Channels of the Continental shelf and the Deep one of the Connecticut.*

The surface of the continental shelf is a marvellously flat plain, with a mean slope not exceeding three feet per mile. This condition represents a flat substratum, even though there may be hollows in it levelled over by sand deposits. Nearer than Long Island there is no trace of a moraine either buried or submerged. The surface of the plain is covered over with sea-washed sand, except in the Hudsonian channel. This adjective termination I have long used to designate the drowned sections of the river valleys. The sandy plain is traversed by shallow channels shown on each side of the map at AAAA and BBB. These would be still better followed if more isobathic lines were introduced. It is to a depth of 250 feet that these channels are most noticeable. They represent the stream action of an epoch of elevation to this amount since the time of canyon making, and subsequent to the levelling over of the plain after that date. That is to say, these channels absolutely belong to a post-Columbia or Pleistocene epoch,—the canyons to a pre-Columbia or early glacial time. During Columbia oscillations wave action has obliterated all traces of delta form.

The channel of the Hudson river in crossing the submarine plain shows a bottom of blue clay with sandy material in places. But the course of the old upper channel must have been still defined to have allowed its reopening during the epoch of reëlevation of 250 feet just mentioned.

In the canyon section, the bottom is composed of blue clay with fine sand. Beyond it the continental slope is also surfaced with blue clay or green clay, as shown by many soundings.

The great Connecticut canyon or valley, asked for by Lindenkohl,* is represented (at C on the map) by a deep embayment, whose west wall is at least 3600 feet high, and it reaches to a depth of 5736 feet below the surface of the sea, but the information is not at hand to define its form, though a canyon perhaps passing into a valley at this point might be expected.

At D, on the other side of the map, one sees a cove or amphitheatre such as are commonly indenting the borders of high

* Bull. Geol. Soc. Am., vol. xiv, p. 226, 1903.

plateaus. I may have too strongly represented the feature on the map, but it is not one of special importance.

### *Constitution of the Continental Shelf.*

All our classic teaching tells us that, during the earlier and middle Mesozoic era and far into the Cretaceous period, the continent here was so elevated and subjected to denudation that the sediments were carried far seaward. We cannot go into the question as to their covering the continental slope, but it would seem that the continental shelf now submerged was subjected to the same conditions as those now underlying the coastal plains of the adjacent lands. On these we learn that besides a few hundred feet of Potomac sands, which probably thin out, there are deposits of sand, greensand, clay and clay marl of the upper Cretaceous formations reaching a thickness of 800–1100 feet. Then follow some Eocene sands succeeded by clayey, marly and sandy beds belonging to the Miocene beds. These occur in an artesian well boring at Atlantic City, reaching to a depth of 1400 feet (without penetrating the series or the limited Eocene sands or obtaining water at the lower depths though somewhat higher fresh water occurs, indicating the leaching out of the salt sea water during an epoch of elevation). All below 265 feet is Miocene. This upper part is composed of sand gravel and clay, which may represent important features requiring a word of explanation. Of red gravel sand and stiff clay loam are composed both the Lafayette and Columbia formations, each of which is a thin sheet except where filling valleys. The Lafayette is provisionally regarded as belonging to the end of the Pliocene period, occurring below morainic material as I have seen in New Jersey. But it has been enormously denuded. The Columbia formation (now subject to subdivision) is the material of the Lafayette redeposited, and overlies the drift, with its surface only moderately sculptured. I should suspect that at Atlantic City is a buried channel filled mostly with these deposits of the Columbia period, capped with more recent alluvium. These upper beds are substantially horizontal, with the Miocene dipping a litttle more. For the details of the Miocene deposits in the Atlantic City well see the paper by Mr. L. Woolman*.

Thus not knowing whether these incoherent formations have a greater or less aggregate thickness, beneath the submerged coastal plains, there are only known little over 2200 feet to be accounted for from the adjacent shores. But they have formed the subsurface of the level plains now submerged, and channelled by the drowned Hudson river, and finally incised by

* Acad. Nat. Sc., Phil. 1887, p. 339, and vol. for 1890, pp. 132–147.

the canyon on the continental border. Here then, in its upper portion, the gorge penetrates easily denuded material, though some of the beds are composed of remarkably tough clay. Where the sides of the canyon are so precipitous as was shown at the 459 and 801-fathom isobaths, we may suppose that the lower portions are cut out of the harder older rocks, succeeded by more yielding material farther down the submarine valley.

### *Origin of the Canyon*

It appears that the previous students of the submarine channel have all had the idea that it was formerly a land valley. Such analysis of the phenomena as has been given must be used in discussing its origin under any other hypothesis. While a few other soundings are desirable for fuller local details, we need not one more for a reasonably full discussion of the principles involved—only enough are wanting to stimulate interest in a revision. Not to speak of similar phenomena farther south and in the West Indies discovered by myself,* and those since brought to light and systematized in a brilliant manner by Prof. Edward Hull of London, situated on the eastern side of the Atlantic basin,† I shall mention the canyon of the Congo discovered by Stassano, and worked out by Mr. J. Y. Buchanan and described by Mr. Edward Stallibrass, and the canyon off Cape Verde described by Mr. Henry Benest, on account of the completeness of detail of such features, not hitherto obtained, but with which the Hudsonian canyon can now be grouped with the advantage of our knowledge of the surrounding physiographical and geological environments, and with the further interest in that it is situated at the main door of the continent.

If formed by river action, the Hudsonian canyon affords proof of startling physical conditions of the region, at a very late date, and hence the whole interest in its origin, for if now a land feature, it would be one of not such unusual occurrence as to awaken our amazement. Can the views of the earlier writers be challenged? The only other possible causes of its origin seem to be:—(1) submarine glacial erosion, (2) open faults, (3) submarine rivers, and (4) a remnant of a primitive depression. This last would only be suggested by an obstinate objector to its fluviatile origin, or one unfamiliar with the analyses of such subjects; for after passing the Paleozoic evolution of the continent, what is now its great slope should be covered with detritus carried into the sea during the long period of denudation of the Mesosoic era, thus obscuring older depressions. Some of the African canyons have been attrib-

* "Reconstruction of the Antillean Continent" and other papers in Bull. Geol. Soc. Am. and in Quar. Jour. Geol. Soc. London.

† Published by the Victoria Institute, London.

uted to submarine rivers. By this the hypothesis of a great elevation of the continent was avoided. There seems nothing in its favor beyond the occurrence of river valleys at great depth, and some floating debris on the sea. As Prof. N. S. Shaler says, subterranean channels must be formed above the base level of erosion; and the establishment of such must precede that of submarine rivers, which soon lose their effectiveness.

Can the question of canyons be cavalierly disposed of by calling them faults? The level continental shelf is covered with Tertiary sands and clays, such as would not favor an open fault theory. The submarine topography on both sides is identical, suggesting not the slightest disturbance to leave an open fault, nor is such shown on the land adjacent. Joints and faults may locate valleys, but the submarine shelf is only a new plain prolonging the Hudson valley, which in slowly rising would force the water to follow the lowest course. The fault theory is not supported by the Great Valley of the Appalachians, extending for a thousand miles, with a breadth of from 20 to 40 miles. And it is in a region abounding in fault; yet the valleys, as have long since been shown by Professors Lesley and Dana, and others, are those of denudation and which I have confirmed in Georgia. Even the gorge of the Delaware Water Gap, where more than a tyro might be pardoned for suspecting a fault left open, is not such according to Professor Lesley and Mr. Chance the geological surveyor of it. The submarine canyon of the Hudson, which is double, the inner the more sinuous, does not lie in a direct line, but turns twice at right angles within a distance of a dozen miles, and below, it widens into a fan-shaped valley. Nansen has described many submarine valleys in the continental shelf of Norway and about Iceland, and does not find it necessary to call in the existence of faults, and even where my evidence has not been full in treating deep submarine valleys, he thinks there is no other feasible explanation, than that the valleys are sunken land features (page 192). Nor will those who appeal to Sir A. Geikie find much comfort in faults. He says:—"To many geologists the mere existence of a valley is evidence of the presence of a fault," and that "in every case actual proof of a fault should be sought for in the tectonic structure of the ground." "In the vast majority of cases in Britain valleys have no connections with faults." From its forms and its associations I think we can dispense with the idea of a fault-made rift, unaffected by atmospheric action; and furthermore, this is not in the region of apparent great tectonic disturbances, but one of remarkable simplicity since in Cretaceous times.

Finally I know of no other reason for appealing to faults as

the cause of such a submarine feature, except as a last resort from accepting the evidence as is set forth in this paper, unless such a reason can be shown to exist other than by negative or insufficient evidence.

As for submarine glacial erosion, I have shown that there are no features of the shelf suggestive of the occurrence of glacial action, even though such reached to Long Island and New Jersey. Furthermore it could not have possibly extended to the great depths of the canyon and the continuing valley. Of this question Dr. Nansen says in his great monograph:—"The drowned valley of the Hudson River cannot possibly have been re-opened by submarine glacial erosion, it is too long and narrow and deep." (Op. cit. p. 192.) Its analogues of the tropics are situated beyond glacial action.

Of the drowned valley of the Gulf of St. Lawrence, Prof. N. S. Shaler also writes, but I do not remember whether he considers the then discovered Hudson River canyon.

Returning now to long accepted fluviatile origin of the submarine channel, let me call attention to the very close resemblance of the canyon, as shown on the map, to the gorge of the Niagara, also excavated out of level plains, far from mountains, in front of which are great slopes to lower levels. But this portion of the Hudsonian canyon is thirty miles long and reaches to thousands of feet in depth, while that of the Niagara is only seven miles in length and now 440 feet deep. So too the canyon of the Hudson is just like the *barrancas* on the high plateaus of Mexico and Central America, starting in level plains, and then suddenly transforming themselves into rapidly descending canyons, which later widen out into such valleys (as we may see in the east, which have reached more mature forms), whose descent from the plateaus of thousands of feet in height is not by regular gradients, but commonly by a succession of great steps.

### *The Magnitude and the Time of the Great Elevation.*

While it must have taken the Hudsonian canyon many milleniums to have been formed, yet it presents a youthful feature, in strong contrast with the valleys on the eastern side of the American continent, while its submerged marginal shelf is not deeply indented with its surface scored into a succession of ridges and hollows. Even though many of the underlying rocks may be of a resisting nature, yet the period of canyon-making must have been one of limited duration. This is further suggested when considering the size of the Hudson river, which probably carried down glacial waters and detritus for a portion of the period. Outside the limit of the Hudsonian river, the surface of the now submarine plain was

not deeply scored as with atmospheric agents acting for long ages, as would have appeared beneath the superficial mantle had such obtained. One condition might modify this last argument, namely a subsequent long epoch of wave cutting, with the removal of the prominences, such as Nansen describes in his "coast platform" which does not exist here, but in such a case the Hudsonian gorge should have been filled with debris.

In the region of the Great Lakes from the tilting of beaches, I have worked out great epirogenic movements, and it quite prepares me to expect to find a reduction of the amount of elevation of the continent, represented by the present submergence of the valleys along our continental margin due to bending downward of the continental slope, but this would not reduce by any amount that determined in the canyons and the necessary slope of the land surfaces. So also when we find subaerial features submerged, they at least would need to have been depressed to the depth they are now found at, no matter what the cause of depression.

The canyon section has sunken 6,000–7,000 feet and the valley beyond to 9,000 feet. Did I attempt to guess at the reduction of this amount in the late height of the continent, I should be inclined to pause owing to other features outside the line of this study. But if others wish to reduce the continental elevation by 2,000 feet, by extra bending down of the continental slope, I shall not protest farther than by stating that additional evidence beyond our limit may replace it. Provisionally then we may keep the amount of elevation at 9,000 feet as shown here, leaving others to correct the figures if found to be excessive. On the other hand, I have no idea that the present heights of the mountains were relatively nearly so great as now.

Fragments of the Lafayette formation should extend from New Jersey, and underlie the surface of the continental shelf. The great denudation of the region was after the Lafayette period, as was proved by Prof. W. J. McGee. I have found these beds underlying glacial deposits in New Jersey. They are provisionally regarded as Pliocene, unless they are preglacial Pleistocene, as thought by Upham. On the surface of the overlying till, rests the Pleistocene Columbia red loams, sands and gravels, in samples not distinguishable from those of the Lafayette formation except in the smaller size of the gravel. And it is such materials which are obtained in the Atlantic city well (Woolman). The denudation of the Lafayette has been so extensive that its remains would be more likely outside of a channel, buried as this appears by the Columbia formation, which has levelled over and furnished materials for the surface of the continental shelf before the

re-excavation of the small channels at AAAA and BBB on the map (page 2). These channels as mentioned before, represent a re-elevation of the drowned plain to as much as 250 feet in the later Pleistocene period, since which time the region has been again once or twice depressed, then re-elevated slightly and channelled, and is now sinking at the rate of two feet a century (Prof. Mitchel). All of the changes are remarkable repetitions of those which I have shown to have occurred farther south and in the West Indies. Thus it may be seen that the canyon-making period was in the earlier Pleistocene, and accords with Prof. Dana's views as expressed in the last edition of his Manual, and those of Dr. Upham, only the evidence is in more detail, showing a much greater elevation than was then known.

I have not touched upon an earlier Tertiary valley, as such could apply only to great depths beyond the canyon section.

*Summary and Conclusion.*

More than 40 years ago, Prof. J. D. Dana first recognized the submarine extension of the Hudson river in the soundings on the continental shelf. In 1885, Prof. A. Lindenkohl discovered the channel suddenly transformed into a canyon near the continental border, reaching to a depth of 2400 feet below the surface of submerged plain, which is here about 400 feet beneath sea-level. But near the then known mouth there appeared a great bar. In 1897, I pointed out that the channel was traceable to great depths, which is now proved. A sounding was made near the supposed bar, which has proved to be only a measurement taken on the side of a deep canyon with a precipitous wall. Then four miles beyond this point, against another lateral bank, a further sounding reaches to 4800 feet, revealing a canyon 3800 feet in depth, where the continental shelf is not submerged more than 1000 feet. High up on the sides, the gorge here is less than two miles wide, but the incision of the outer canyon into the shelf has a breadth of four miles. At its head, the canyon begins in an amphitheatre, having a descent from 330 feet to 1100 feet in the distance of about a mile. Two more steps of 400 and 500 feet respectively follow. Again between 27 and 31 miles below its head, there is another great step of 2000 feet to the depth of 4800 feet mentioned. And the gradient below is probably by other great steps. This is just beyond the border of the submarine plain and shows the canyon with a depth of 3800 feet. The canyon is double, a second or more sinuous gorge traverses the outer. A little farther on is a tributary heading in a cove. At 42 miles the canyon begins to widen into a valley, which at 48 miles has a precipitous wall of 2000 feet in height. The valley opens

into an embayment or wider valley which also receives that from the Connecticut, now discovered to a depth of about 6000 feet for the first time, but without details to describe its form. In cutting through the continental bench, at 3000–3500 feet beneath sea-level, the floor of the canyon is between 6000 and 7000 feet below the surface of the ocean. The valley is continuous to a point 71 miles from the head of the gorge and where it is recognizable at a depth of about 9000 feet.

The canyon and valley discovered to the great depth shown, incising first the level continental shelf, (in which it turns twice at right angles), and then coursing down the great continental slope, is now taken as a gauge for measuring a late high continental elevation of the region to the extent of 9000 feet. This is following out the lines of Dana, Lindenkohl and other students of the submarine channel, in that they considered it a drowned land valley. I have analyzed every other known possible cause of its origin. So great are the probabilities and so long have these been accepted unquestioned, that very strong proof would be required to modify this view.

The period of the great elevation has been found to coincide with that of the early Pleistocene. Since then there has been a subsidence to somewhat below the present level, followed by a re-elevation of 250 feet as seen in the shallow channels of the shelf. With other minor changes, the region is now sinking at the rate of two feet a century.

This canyon feature at our door corroborates the great changes of level worked out most extensively by Hull of Britain, Nansen of Norway, and myself here and in the West Indies, following methods which the father of geography, Prof. J. P. Lesley, predicted in 1888 "must throw light on the whole subject of elevation and subsidence, as applicable to the entire area of the United States."

## Art. II. — *Radio-activity of Underground Air;* by H. M. Dadourian.

Atmospheric and underground air have been shown to be radio-active by Elster and Geitel,* and others. Experiments, by several investigators, on the rate of decay and other properties of the atmospheric radio-activity have proved it to be due to the presence of a radio-active gas similar to radium emanation. The activity of this radio-active gas decays just about as fast as radium emanation, that is, it falls to half value in about three days and a half. But the rates of decay of the excited activities obtained by exposing a negatively charged wire to the air and to radium emanation do not agree so well. Rutherford and Allan† obtained 45 minutes for the half-value period of air excited activity, whereas radium excited activity falls to half value, after the first two hours, in 28 minutes.

This is to be expected if we suppose that there is thorium emanation in the air as well as radium emanation. Thorium emanation decays very rapidly, having a half-value period equal to about one minute; so the experiments on the rate of decay of the radio-active gas obtained from the air determine the rate of decay of the radium emanation in the air only, the thorium emanation having decayed during the few minutes which it takes to begin to observe the ionization currents, after the removal of the difference of potential from the negatively charged wire. This accounts for the close agreement between the rates of decay of the ionizations of radium emanation and the radio-active gas obtained from the air. On the other hand, the excited activity obtained by exposing a negatively charged wire to the air, decays very much more slowly than radium excited activity; the half-value period of the former is about 11 hours while that of the latter is 28 minutes. Thus measurements of the rate of decay of the air excited activity give the rate of decay of a combination of the excited activities of radium and thorium. In fact, Bumstead‡ has recently shown that the excited activity obtained by exposing a negatively charged wire in the open air is fairly accounted for by the assumption of the presence of radium and thorium emanations in the air.

The following experiments were undertaken in order to see if this was the case with the excited activity obtained from underground air, also. The method employed in taking the ground-air excited activity is illustrated in figure 1.

* Elster and Geitel, Phys. Zeit., iii, p. 574, 1902.
† Rutherford and Allan, Phys. Mag., Dec., 1902.
‡ Bumstead, this Journal, xviii, 1, 1904.

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A circular hole, AA, 50$^{cm}$ in diameter and 200$^{cm}$ deep, was dug in the ground. At the top of the cavity was plastered a rectangular board, CC, with a circular opening 40$^{cm}$ in diameter. A sheet metal cover, D, screwed on to the board, over a rubber gasket, served as a partition between the outside air and the air inside the cavity. BB is a wooden frame, which consists of a 175$^{cm}$ long rod, provided with a circular board, of 30$^{cm}$ diameter, at each end. A piece of copper wire, $\frac{1}{4}^{mm}$ thick and about 50 meters long, was wound about the frame, so as to form a cylinder. The wire was put into this form in order to have it as near the walls of the cavity as possible, also to secure a larger field. This cylinder of wire was then hung from a hook, E, which was insulated from the sheet metal cover and was connected to the negative terminal of a Wimshurst machine, the other terminal being to earth.

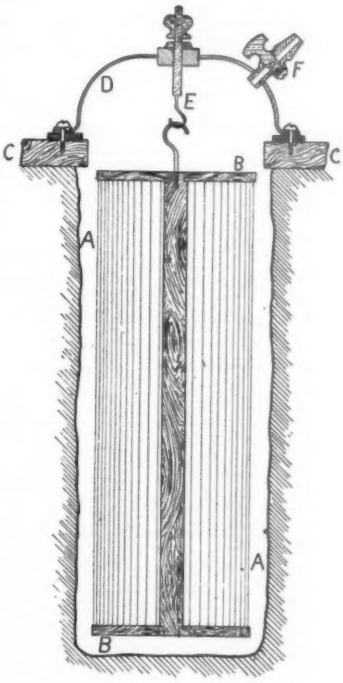


FIG. 1.

The wire was charged for three hours, keeping a parallel spark-gap of about 2$^{mm}$. In the meanwhile the air in the cavity was sucked out by means of a filter pump, connected to the stopcock, F, in order to bring fresh underground air into the field of the negatively charged wire. At the end of three hours the wire was removed from the wooden frame and was put into a testing vessel. This was a cylindrical condenser which consisted of a galvanized sheet-iron cylinder and a central brass rod, insulated from the cylinder and connected to one pair of the quadrants of an electrometer.* The needle of the electrometer and the testing cylinder were connected to the negative electrode of a set of dry cells giving a potential difference of 105 volts, the other electrode of the

*For a description of the electrometer, the testing cylinder and connections, see February (1904) number of this Journal.

battery being to earth. The central rod of the testing condenser and the pair of quadrants it was connected with were earthed ordinarily, but could be insulated at will by pressing a key. The electrometer was very steady throughout the following experiments and had a sensitiveness of 250$^{cm}$ per volt with 100 volts on the needle and the scale at one meter.

The observations were taken in the following manner: The zero position of the needle was observed, then the central rod of the testing vessel and the quadrants it was connected with were insulated. Observations of the ionization current were taken at the end of half a minute, one minute and two minutes

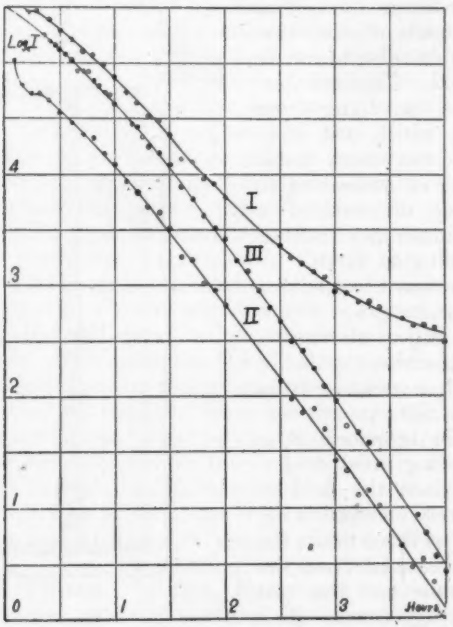


FIG. 2.

after the quadrants and the central rod were insulated; then these were earthed again. This was done at six-minute intervals for five hours, after which the activity of the wire decayed very slowly, and it was not necessary to take observations so frequently. The decay of the activity for the first four hours is given by curve I of figure 2, where the time is plotted as abscissae and the natural logarithms of the ionization currents as ordinates. The experiment was continued for three days,

observations being taken at longer intervals. About five hours after the potential difference was removed from the negatively charged wire, the ionization due to radium excited activity was vanishingly small, all the activity, about five per cent of the total initial activity, being of a very much more slowly decaying type. The rate of decay of this slowly decaying activity was calculated from the data of two experiments; in one case the half-value period was 10 hours and 12 minutes, and in the other case it was 10 hours and 47 minutes, giving an average value of 10½ hours. This is very near the half-value period of thorium excited activity, which is about 11 hours. None of the excited activities of the known radio-active substances or a combination of them can account for the slowly decaying excited activity of ground air, except thorium excited activity.

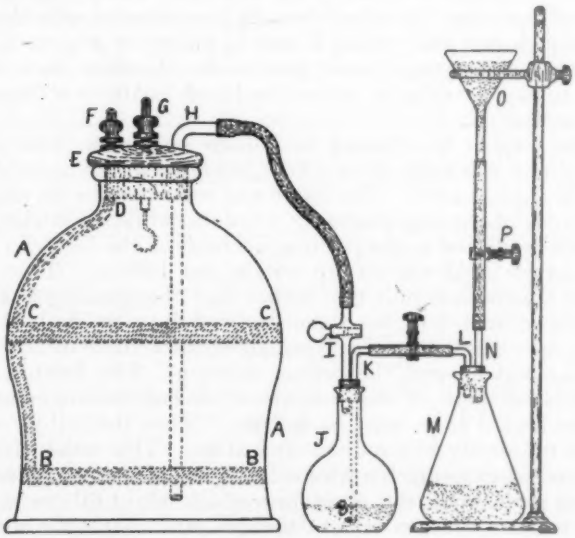


FIG. 3.

It is very improbable that there is an unknown radio-active substance whose excited activity falls to half-value in about the same time as that of thorium. Hence there is no reason to doubt that the slowly decaying activity obtained by exposing a negatively charged wire to underground air is thorium excited activity.

In order to see if the presence in the underground air of radium and thorium emanations was enough to account for the

ground air excited activity, the following experiments were made:

A piece of copper wire, $\frac{1}{4}^{mm}$ in diameter and 2 meters long, was exposed to radium emanation in an apparatus shown in figure 3. The apparatus consists of a glass bell-jar, AA, $22^{cm}$ in diameter and $30^{cm}$ high. It is fitted with an insulating cap, E, provided with two binding-posts, F and G. The binding-post F is in contact with a strip of tinfoil, DCB, and through that with two other strips of tinfoil, CC and BB, all three being pasted inside the bell-jar. J is a flask containing a solution of radium bromide of 1000 activity, prepared by De Haan. A glass tube, I, provided with a glass stopcock, is connected by a piece of rubber tubing to another tube, H, which passes through the insulating cap, E, into the bell-jar and puts the latter in communication with the flask which contains the radium solution. Another flask, M, is connected with the flask J through two glass tubes, K and L, joined by a piece of rubber tubing carrying a screw pinchcock. Another piece of rubber tubing carrying a screw pinchcock connects a funnel, O, to the flask M.

The wire to be exposed to radium emanation was loosely coiled and was hung from a hook soldered to the lower end of the binding-post G. The latter was connected to the negative electrode of a storage battery of 100 volts, while the binding-post F was connected to the positive electrode of the battery. Thus an electric field was set up within the bell-jar. Then some water was poured into the funnel and the pinchcock, P, was regulated such that the water dropped into the flask M, drop by drop. Each drop displaces an equal volume of air, which bubbles out through the radium solution. This bubble in its turn forces part of the mixture of air and radium emanation in the flask J to go into the bell-jar. Thus the bell-jar is supplied uniformly with radium emanation. This rather elaborate method of exposing the wire to radium emanation was used to guard against particles of radium which might otherwise come into contact with the wire or the bell-jar. After the wire was charged for exactly three hours it was taken out of the bell-jar, was introduced into the testing cylinder and observations of the ionization currents were taken as described above. The results of the experiment are shown by curve III, figure 2.

The rate of decay of thorium excited activity also was taken by exposing a piece of copper wire, of the same dimensions as the one used for radium excited activity, to thorium emanation. The source of the emanation was about 10 grams of powdered thorium oxide, which was spread uniformly over a watch-glass and placed under the bell-jar. The wire was

charged negatively for three hours and the rate of decay of the activity was observed as before. The results of two such experiments are shown by curves I and II, figure 4, where the ordinates represent the ionization currents and the abscissae the time. These curves have half-value periods of about 11 hours and agree very closely with those given by Rutherford.

The component due to thorium of the total ionization of the ground-air excited activity was calculated by a method to be described below, and was subtracted from the latter in order to compare the result and activity with radium excited activity. It is obvious that the resultant activity will be nothing more nor less than radium excited activity provided that the ground-

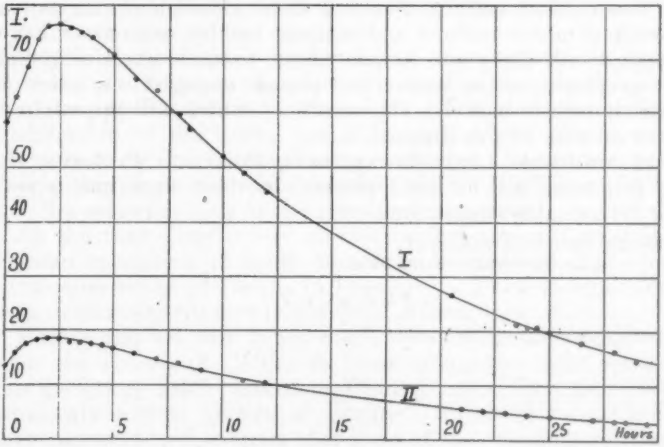


FIG. 4.

air excited activity is composed solely of radium and thorium excited activities. It was shown above that the activity of the negatively charged wire exposed to ground-air was entirely thorium excited activity at the end of five hours after the removal of the potential difference from the wire. Hence the thorium element of the ground-air excited activity at any time can be found by multiplying the ionization of the thorium excited activity, for the corresponding time, by the ratio of the ionizations of the ground-air and thorium excited activities at any time after five hours. The ratio of the ionizations, at the end of nine hours of the ground-air and thorium excited activities, represented by the curves I of figures 2 and 4 respectively, was found to be 0·0216. Each of the observed values of the ordinates of curve I, figure 2, was multiplied by this ratio and

the product was subtracted from the former. The results when plotted gave curve II of the same figure, which represents the rate of decay of the ground-air excited activity minus the part due to thorium. A glance at figure 2 is enough to show the difference both in nature and rate of decay of curves I and III on one hand, and the agreement between the curves II and III on the other. Yet it will be observed that the latter are not exactly parallel; curve II slopes at a little slower rate than curve III. Hence apparently the ground-air excited activity decays at a slightly slower rate than a combination of radium and thorium excited activities, in the same proportion as they occur in the ground-air excited activity. Bumstead has observed a similar disagreement between the rates of decay of the excited activity obtained from atmospheric air and a combination of radium and thorium excited activities.* No attempt will be made in this paper towards explaining the disagreement, as the writer is at present engaged in a series of experiments to that end, the results of which will appear in a later number of this Journal.

In conclusion, I wish to express my thanks to Professor H. A. Bumstead for his kind interest in these experiments and for his valuable suggestions.

Sheffield Scientific School of
Yale University, Nov., 1904.

* Loc. cit. p. 7.

## Art. III. — *The Types of Limb-Structure in the Triassic Ichthyosauria;* by John C. Merriam.

### *Introduction.*

Of the numerous valuable contributions to paleontological literature made by the late Professor George Baur, one of the most interesting was that in which he furnished evidence that the limbs of the Jurassic Ichthyosaurs were highly specialized structures developed in adaptation to aquatic life.* In advancing this view he opposed the theory of Gegenbaur and others, who held that they were generalized and intermediate between the pentadactyle limbs of the higher vertebrates and the many-rayed extremities of the selachians. As was shown by Baur, the limbs of the Triassic Ichthyosaurs come nearer to the type of extremity found in the primitive reptilia than do those of the later representatives of the order. The character of the modification of the limbs, and in fact the whole structure of the body in the later Ichthyosaurs, indicated to him that, as a group, they bore the same relation to the Rhynchocephalia that the cetaceans bear to the primitive mammals.

At the time Baur wrote on this subject, the only available Triassic specimens showing the limbs were those from the bituminous shales of Besano in Lombardy. These he separated from *Ichthyosaurus* as a new genus, *Mixosaurus*.

Within the last few years considerable collections obtained from the Triassic of California have brought to light several new groups of Ichthyosaurians differing not a little from the previously known genera of Europe. So many new forms have appeared in this fauna that some of the questions relating to the origin and descent of the Ichthyosauria are reopened. The addition of new material has made the problems more complicated, but it is hoped that before we again reach the limits of profitable discussion it will be possible to add something to our knowledge of the origin and the history of the group.

### *Characteristics of known types.*

At the present time we are acquainted with not less than four types of limbs in the Triassic Ichthyosaurs. One of these is represented in *Mixosaurus*, a second in the genera *Toretocnemus* and *Merriamia*,† a third in *Shastosaurus osmonti* and

* Ueber den Ursprung der Extremitäten der Ichthyoptergia, Ber. d. xx, Versamml. d. oberrhein. geol. Ver., xx, p. 3.

† See G. A. Boulenger, Proc. Zool. Soc. Lon., 1904, vol. i, p. 425. *Leptocheirus* Merriam being preoccupied is replaced by *Merriamia* Boulenger.

*alexandrae.* The fourth appears in a recently discovered specimen which seems to be specifically identical with *Shastasaurus perrini.* This form evidently represents a genus distinct from the type seen in *S. osmonti* and *alexandrae*, and the name *Delphinosaurus** may be used to distinguish it from the more specialized species.

In *Mixosaurus* (fig. 1) the extremities are of a primitive type. Both manus and pes are pentadactyle,† the elements of the limbs are generally quite slender and in many cases have a median constriction. This form is farther characterized by the articulation of the intermedium distally with two or more elements and by the frequent presence of a fourth element (pisiform) on the posterior end of the proximal row in the mesopodial region.

*Toretocnemus* and *Merriamia* do not differ greatly in limb structure though the vertebrae are of distinct types. In *Merriamia* (fig. 2) the limb has but three digits with the merest vestige of a fourth. There are but three elements in the first row of the mesopodial region and both carpus and tarsus are of a strictly linear type, the intermedium articulating with but a single element distally. In this genus the posterior limbs are much smaller than the anterior. In *Toretocnemus* the posterior limbs equal or exceed the anterior in size and the vestigial fourth digit of the posterior limb appears to have been larger than in *Merriamia.*

The most specialized limb found in the Triassic genera, and one of the most specialized types known in the Ichthyosauria, is seen in *Shastasaurus osmonti* (fig. 4). The anterior limb in this genus is characterized by extreme shortening of all the elements. The humerus is actually as broad as long and is one of the shortest propodial elements known in the reptilia. The epipodial bones are also greatly abbreviated, though separated by a narrow cleft. Of the carpus only the radiale is known. It is as large or larger than the ulna and its margin is entire, while that of the radius shows an anterior notch.

In the recently discovered anterior limb referred to *Delphinosaurus (Shastasaurus) perrini* (fig. 3) the humerus, radius and ulna are longer than in *S. osmonti*, and the radius and ulna are both deeply constricted. The radiale is narrower and is notched. The carpus is of the linear type and the posterior of the three linear series consists of somewhat smaller bones than are seen in the other two. The elements of the meso-

* *Delphinosaurus* is characterized by much elongated vertebral centra; an unnotched scapula, and the peculiar structure of the limbs described above.

† See redescription of *Mixosaurus*, E. Repossi, Atti. della soc. ital. d. scien. Natur., vol. xli, fasc. 3, p. 361–372, Tav. viii, ix.

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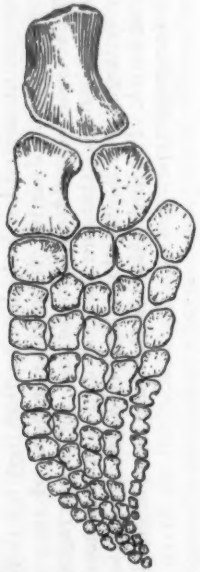

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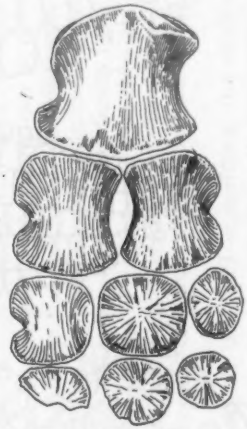

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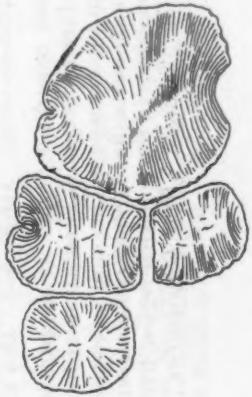

FIG. 1.—*Mixosaurus cornalianus*. Left anterior limb. × ½. Slightly modified from Repossi.

FIG. 2.—*Merriamia zitteli*. Left anterior limb. × ½.

FIG. 3.—*Delphinosaurus perrini*. Left anterior limb. × ½.

FIG. 4.—*Shastasaurus osmonti*. Left anterior limb. × ⅛.

podial and phalangeal regions, as far as known, are rounded and have deeply excavated borders, showing that they lay in heavy pads of cartilage. Judging from the character of the carpus in *Delphinosaurus* and in *Merriamia*, the large radiale in *S. osmonti* indicates that the anterior digit of the manus was relatively larger and the third smaller in *Shastasaurus* than in the other forms. The limb would in that case be reduced almost to a two-fingered type.

### *Degree of differentiation.*

The degree of differentiation shown in the three or four types of limb structure known in the Triassic Ichthyosaurs

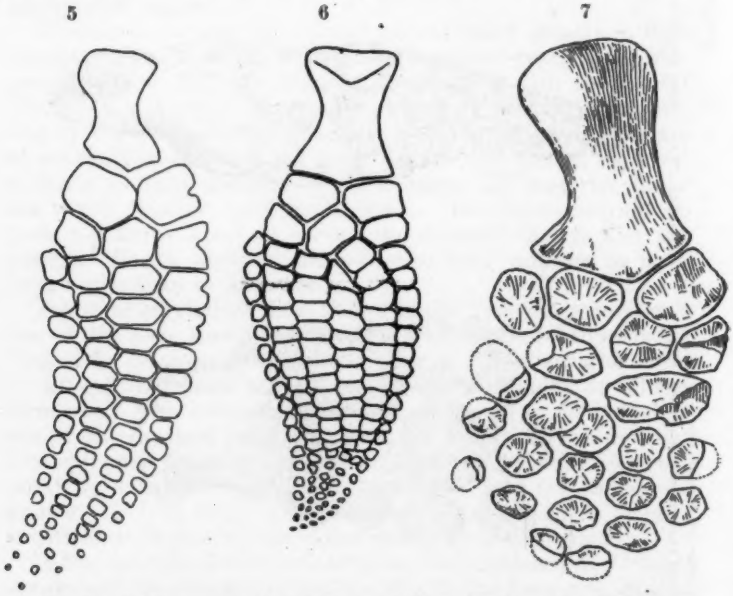


FIG. 5.—*Ichthyosaurus quadricissus.* Anterior limb. ×⅓. After Fraas.
FIG. 6.—*Ichthyosaurus conybeari.* Anterior limb. After Lydekker.
FIG. 7.—*Baptanodon marshi.* Anterior limb. After Knight.

appears quite remarkable when we compare it with what we find in the Jurassic genera. Three types of limb structure are known from the Jurassic. The most specialized of these is found in *Baptanodon* (fig. 7) and *Opthalmosaurus* with three very short elements in the epipodial region, five or more digits, and discoidal phalanges. In *Ichthyosaurus*, possessing two

short epipodial elements, there are two groups. Of these the Longipinnati (fig. 5) have an essentially linear mesopodial region, a notched radius and usually three to five digits. The Latipinnati (fig. 6) have an alternate arrangement of the mesopodial region caused by the articulation of two or more distal elements on the intermedium; there are generally between five and ten digits; and notches are rarely present on the phalanges, while never on the radius. Compared with these three types the Triassic forms show an unexpected degree of differentiation.

### *Primitive characters.*

In spite of the differentiation shown in the Triassic types, they have all retained certain primitive characters not common in the later forms. All show a separation of the radius and ulna, and in all excepting *Shastasaurus osmonti* these elements are elongated and the radius is constricted or shafted. The presence of these and other primitive characters in so many otherwise different forms furnishes us with much stronger evidence of the origin of the Ichthyosauria from generalized shore forms than could have been given by the single type known to Baur.

### *Lines of descent.*

A comparison of the Jurassic and Triassic genera of Ichthyosaurs with a view to determining the lines of descent shows immediately that no known Jurassic form can be considered as having descended from the specialized *Shastasaurus*. So far as we now know, this group disappeared in the Triassic. *Baptanodon* and *Opthalmosaurus* are also practically excluded from any comparison with the Triassic genera, as they are comparatively late forms and could be derived from the latipinnate Ichthyosaurs as easily as from any of the much older Triassic types.*

The views which we hold concerning the descent of the remaining Jurassic groups involve our interpretation of the homologies of the elements in the Ichthyosaurian paddle. On this subject a considerable variety of opinion has been expressed, particularly with reference to the relationships of the mesopodial elements.

Some years ago Lydekker† suggested that the most generalized type of limb in the Jurassic Ichthyosaurs is found in the

* Dr. O. P. Hay (Bull. 179 U. S. G. S., p. 463) has, I believe inadvertently, placed the West-American Triassic Ichthyosauria under the Baptonodontidae. Based on this suggestion, Boulenger (loc. cit.) has indicated the descent of *Opthalmosaurus* from *Shastasaurus*. The writer is obliged to regard these groups as probably the most widely separated of all the known Ichthyosauria.

† Geol. Mag., 1888, Decade 3, v, p. 310.

Longipinnati, such as *Ichthyosaurus tenuirostris*. The anterior digit was considered as representing digit II of the primitive limb, digit I having disappeared. Latipinnate forms, such as *I. intermedius*, were supposed to be more specialized, the additional digit in the middle of the hand having been produced by the splitting of digit III. The longipinnate group would then be the more primitive and the latipinnate forms be derived from it by intercalation or splitting of digits.*

Strongly suggestive of the latipinnate and longipinnate paddles we find also in the Triassic genera a broad and a narrow type, the broad form occurring in *Mixosaurus*, the narrow form in all of the Californian genera. In the narrow type the limb is even more reduced than in the Longipinnati and is really tridactyle. So far as can be determined, *Toretocnemus* seems to be the most primitive of these forms. The rudimentary fourth digit is larger than in the others and the third digit is as large as the first. In *Delphinosaurus* the third digit is much smaller than the others and in *Shastasaurus osmonti* it was probably smaller than in *Delphinosaurus*. This series showing progressive reduction of the posterior side of the limb indicates that the type is probably not a primitive one, but is derived from an earlier form with five digits.

While we can understand the origin of the narrow type of paddle in the Trias, the broad form is not so easily explained if we hold that digit number one has disappeared. *Mixosaurus* had five digits of nearly equal size and made up largely of the shafted or primitive type of phalanges. The extremities of this form were, however, *already specialized paddles*, and, if the interpretation of the structure of the paddle of *Ichthyosaurus* given above is correct, we shall have to suppose that in this form digit I was lost and another digit added.

If finger I in *Mixosaurus* corresponds to primitive digit II, the added digit is either below the intermedium or on the posterior border of the limb. The presence of a supernumerary ossicle behind the carpus seems to give support to the idea that the last digit is not primitive, as elements of this character are known to develop secondarily, particularly on the posterior borders of the limbs of aquatic forms. Their presence does not prove the case, however. The supernumerary ossicle may be secondary and the digit primitive, or the presence of the ossicle may be due to upward movement of the last digit along the posterior side of the carpus. Such movements have occurred frequently in Ichthyosaurian paddles, regardless of the theory by which we account for them.

To suppose that one of the digits below the intermedium is

*Mr. Lydekker has recently expressed himself as in accord with the views concerning the primitive character of the Mixosaurian paddle which are presented in this paper. See p. 29.

of secondary origin would seem almost a violent assumption. That splitting and intercalation of digits have occurred in some of the broad-paddled Ichthyosaurs is beyond question, but evidence of the character which we find in these forms is lacking in the paddle of *Mixosaurus*. The digits are of equal size and their relations to the intermedium are such as one might expect to find in a fairly primitive limb.

Though there is a tendency for the short first digit to disappear in the evolution of a natatory limb, it has not always done so, as for example in the Plesiosaurs. Farther, in the history of the Ichthyosauria two quite distinct types of paddles have appeared; the broad form, illustrated in the Latipinnati and in *Mixosaurus;* and the narrow form, represented in the Longipinnati and in the Californian genera. In all probability the course of evolution has in all cases been fairly direct. That is, the broad paddles have tended toward greater width and the narrow ones toward slenderness. It is not easy to imagine that after limbs had been reduced to a narrow type they would again increase in width. There is therefore good reason to believe that *Mixosaurus* and the Latipinnati have retained the first digit.

If the first digit in the limb of *Mixosaurus* represents digit I of a primitive pendactyle form, this type may be considered as the most generalized known in the Ichthyosauria. If, on the other hand, the first digit represents number two of the primitive form, the limb can hardly be considered as less specialized than the tridactyle form seen in *Merriamia*, one form having lost two digits, the other having lost one and gained one. Supporting the first suggestion we have the fact that *Mixosaurus* is the oldest described form in which the limb structure is known. The beds in which it occurs are considered by Fraas as the equivalent of some portion of the Middle Triassic, while the Californian genera belong to the Upper Triassic. Evidently *Mixosaurus* is the only described genus which could be considered as ancestral to the Jurassic forms. In the other genera the reduction of the digits has gone farther than in the Jurassic Longipinnati.

It is not impossible that other forms with wider paddles will be found in the American Trias, but up to the present time only the leptochirous or narrow-paddled group seems to be represented. These forms may be closely related to the Longipinnati or may represent a branch of the order which diverged and specialized early. The Longipinnati and Latipinnati may have developed from a persisting primitive stock after the American Triassic forms had become well separated from the rest of the order.

It should be borne in mind that while the evidence furnished by limb structure is some of the most valuable material that we

can obtain for use in working out the phylogeny of the Ichthyosaurs, it can hardly furnish the whole foundation for a definite classification. Inside the American group there seems to be considerable variation, though as yet we do not know all of the most important characters of these forms. *Toretocnemus* and *Merriamia* have very similar limbs but differ considerably in the structure of the vertebrae and ribs. It is perhaps a significant fact that of the several genera, *Toretocnemus*, with the largest vestigial fourth digit, appears in its general structure to be nearest to some of the earliest forms of Europe, represented by *Ichthyosaurus* (?) *atavus** from the lower portion of the middle Trias.

* Recent comparisons of *Ichthyosaurus* (?) *atavus* with the types of *Mixosaurus* show that most of the known vertebrae of *atavus* are quite different from those of the true Mixosaurs. . So far as is known, they appoach most nearly the type of the true Ichthyosaurs. They may belong to *Ichthyosaurus*, possibly to *Toretocnemus*, or may represent an undescribed genus.

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ART. IV. — *The Interaction of Hydrochloric Acid and Potassium Permanganate in the Presence of Ferric Chloride;* by JAMES BROWN.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXXII.]

LÖWENTHAL* and LENSSEN were the first to show that the titration of ferrous salts by potassium permanganate in the presence of hydrochloric acid as proposed by Margueritte† does not admit of quantitative accuracy because of the evolution of chlorine by the interaction of hydrochloric acid and potassium permanganate, and to propose as a remedy for this source of error the titration of successive equal portions of the ferrous salt to be determined until the readings become constant.

This tendency toward evolution of chlorine in titrations of a ferrous salt by potassium permanganate in the presence of hydrochloric acid as compared with the alleged absence of such tendency in similar titrations of oxalic acid, was explained by Zimmermann‡ on the supposition that the oxidation of the iron proceeds so rapidly as to form oxides of iron higher than the sesquioxide which then react to oxidize more iron and liberate chlorine from hydrochloric acid. Quite recently Wagner§ explains this phenomenon by the assumed formation of chlor-ferrous acid (analogous to chlor-platinic and chlor-auric acids), which is more easily oxidized by the permanganate than is hydrochloric acid under similar conditions. Recent work‖ has shown that there is a slight though real waste of permanganate in titrations of oxalic acid under the conditions named, and that this loss is proportional to the amount of hydrochloric acid present. It still appears, however, that this loss is greater in titrations of ferrous salts than in those of oxalic acid under the conditions named.

Wagner's work in relation to the phenomenon mentioned above has been reviewed very carefully, and it has been found that, although as shown by him more permanganate is required to bring about final coloration against equal quantities of oxalic acid in experiments in which equal quantities of potassium permanganate are digested with a constant quantity of normal hydrochloric acid and a measured volume of tenth normal ferric chloride than when an equivalent quantity of tenth-normal hydrochloric acid is substituted for the tenth-normal ferric chloride, the differences vary within wide limits and disappear entirely if the chlorine formed by the interaction of the potas-

* Zeit. Anal. Chem., i, 329. † Ann. Chim. [3], xviii, 244.
‡ Ann. Chem., ccxiii, 311.
§ Maassanalytische Studien, Habilitationsschrift, Leipzig, 1898.
‖ Gooch and Peters: This Journal [4], vol. vii, 463.

sium permanganate and hydrochloric acid is removed during the digestion. When also the chlorine is thus removed the same quantity of permanganate is required to bring about final coloration whether ferric chloride is present or not. It is found also that the permanganate is entirely destroyed within the limits proposed by Wagner, and that after an hour's digestion, and in fact long before, the permanganate color has entirely disappeared and only the hydrated oxides of manganese, formed according to the Guyard reaction, are visible in the digestion liquid.

Wagner describes no special form of apparatus in his work, and gives no details as to size of flask used to contain the digestion liquids, form of bath, etc., pointing out the fact simply that he used a return-condenser 60$^{cm}$ in length. It was found convenient in the experiments about to be described to use a 250$^{cm^3}$ flask to contain the solutions during digestion, and to heat the solutions in an Ostwald thermostat.

TABLE I.

[9·91$^{cm^3}$ $H_2C_2O_4$ = 20·25$^{cm^3}$ $KMnO_4$]

| $\frac{N}{1}$ HCl cm³. | $\frac{N}{10}$ HCl cm³. | $\frac{N}{10}$ $FeCl_2$ cm³. | $KMnO_4$ before digestion. cm³. | Temperature C°. | Time digestion. min. | $\frac{N}{10}$ $H_2C_2O_4$ cm³. | $KMnO_4$ to color. cm³. | $KMnO_4$ apparently reduced during digestion. cm³. |
|---|---|---|---|---|---|---|---|---|
| 100 | 9·91 | --- | 9·91 | 50 | 60 | 9·91 | 15·89 | 5·55 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·11 | 4·77 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·15 | 4·81 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·07 | 4·73 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·13 | 4·79 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·07 | 4·73 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·08 | 4·74 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·02 | 4·68 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 14·85 | 4·51 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 14·40 | 4·06 |
| 100 | 9·91 | --- | 9·91 | " | " | 9·91 | 15·05 | 4·71 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·60 | 5·26 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·35 | 5·01 |
| 100 | --- | 9.91 | 9·91 | " | " | 9·91 | 15·32 | 4·98 |
| 100 | --- | 9.91 | 9·91 | " | " | 9·91 | 15·88 | 5·54 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·42 | 5·08 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·45 | 5·11 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·95 | 5·61 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·41 | 5·07 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·95 | 5·61 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 16·65 | 6·31 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·75 | 5·41 |
| 100 | --- | 9·91 | 9·91 | " | " | 9·91 | 15·79 | 5·45 |

The experiments of Table I were conducted, as outlined by Wagner, in the following manner: To a 250$^{cm^3}$ flask were added 100$^{cm^3}$ of normal hydrochloric acid (that is a solution contain-

ing 36·4575 grams of the acid to the liter), and in addition either 9·91$^{cm^3}$ of tenth normal hydrochloric acid (prepared by diluting 100$^{cm^3}$ of the normal solution to one liter) or 9·91$^{cm^3}$ of tenth normal ferric chloride. Of approximately twentieth normal potassium permanganate, carefully standardized against ammonium oxalate, 9·91$^{cm^3}$ were then added, and the flask, fitted in a ground joint to a return-condenser 60$^{cm}$ in length and with a bore approximately 3$^{cm}$ in diameter, was heated for one hour in the Ostwald thermostat at a temperature of 50° C. Of tenth normal oxalic acid, 9·91$^{cm^3}$ were then added to the digestion liquid and a measured volume of the same permanganate solution as was added before digestion was run in to color. The difference between the total permanganate used (that is the permanganate added before digestion plus that added to bring about final coloration against the oxalic acid) and the permanganate equivalent of the oxalic acid added gives, according to Wagner, the permanganate reduced during the digestion. The results of these experiments are recorded in the above table.

Here it may be seen that although in general more permanganate is required to bring about final coloration in those experiments in which ferric chloride was used than in its absence, the results show at best wide variation among themselves, and the amounts of permanganate apparently destroyed during the digestion are at all events considerably greater than in the experiments conducted by Wagner under similar conditions. In the experiments recorded in Table I, in the average 4·73$^{cm^3}$ of permanganate were apparently destroyed where ferric chloride was not used, and 5·37$^{cm^3}$ in the presence of ferric chloride; while in Wagner's experiments 0·96$^{cm^3}$ of permanganate was apparently reduced without use of ferric chloride and 1·41$^{cm^3}$ in its presence.

Since, as has been noted above, the permanganate color entirely disappeared in the experiments of Table I, long before the termination of the hour's digestion, while only small amounts of hydrated oxides of manganese varying in color from brown to black were visible in the digestion liquid, it seemed probable that more permanganate was really reduced during the digestion than is indicated in these experiments. Moreover a strong odor of chlorine was noticeable in these experiments and it seemed probable that some of the chlorine, formed by the interaction of the potassium permanganate and hydrochloric acid during the digestion, remained to take part in the oxidation of the oxalic acid introduced, and that, therefore, on running in permanganate solution to color, less of the latter was required than corresponded to the oxalic acid left unoxidized by the residual oxides of manganese. It was, therefore, decided to

remove if possible this chlorine, and to this end a vigorous current of carbon dioxide or air was passed through the digestion liquid while heating. In this way the chlorine was readily removed and starch and potassium iodide paper held in the current of carbon dioxide or air gave no test for chlorine.

The experiments of the following table (II), in which no ferric chloride was used, were conducted precisely as were those of Table I above, except that a vigorous current of carbon dioxide generated in a Kipp generator by action of hydrochloric acid on marble, and washed and dried by passing first through a bottle filled with water and then through a calcium chloride tube, was passed through the liquid during the process of digestion. Because also of the greater ease of measuring out accurately $9{\cdot}90^{cm^3}$ rather than the $9{\cdot}91^{cm^3}$ used by Wagner and in the experiments of Table I above, the former volume of reagents was substituted for the latter in the experiments to follow. It will readily be seen that in the case of tenth normal hydrochloric acid $0{\cdot}01^{cm^3}$ is negligible as compared with the large amount of hydrochloric acid used in the experiments.

The results of these experiments are recorded in Table II.

TABLE II.

| | $\frac{N}{1}$ HCl $cm^3$. | $\frac{N}{10}$ HCl $cm^3$. | $KMnO_4$ before digestion. $cm^3$. | Temperature. C°. | Time of digestion. min. | $H_2C_2O_4$ $cm^3$. | $KMnO_4$ to color $cm^3$. | $KMnO_4$ apparently reduced during digestion. $cm^3$. |
|---|---|---|---|---|---|---|---|---|
| [$9{\cdot}90^{cm^3}$ approximately $\frac{N}{10}$ $H_2C_2O_4$ $= 23{\cdot}52^{cm^3}$ $KMnO_4$] | | | | | | | | |
| I | 100 | 9·90 | 9·90 | 50 | 60 | 9·90 | 22·19 | 8·57 |
| II | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·10 | 8·48 |
| III | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·15 | 8·53 |
| IV | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·11 | 8·49 |
| [$9{\cdot}90^{cm^3}$ approximately $\frac{N}{10}$ $H_2C_2O_4 = 23{\cdot}65^{cm^3}$ $KMnO_4$] | | | | | | | | |
| V | 100 | 9·90 | 9·90 | 50 | 60 | 9·90 | 22·15 | 8·40 |
| VI | 100 | 9·90 | 9·90 | " | " | 9·90 | 21·79 | 8·04 |
| VII | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·24 | 8·49 |
| VIII | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·21 | 8·46 |
| IX | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·24 | 8·49 |
| X | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·23 | 8·48 |
| XI | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·25 | 8·50 |
| XII | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·15 | 8·40 |
| XIII | 100 | 9·90 | 19·80 | " | " | 9·90 | 19·77 | 15·92 |
| XIV | 100 | 9·90 | 19·80 | " | " | 9·90 | 19·83 | 15·98 |
| XV | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·53 | 34·81 |
| XVI | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·47 | 34·75 |
| XVII | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·44 | 34·72 |
| XVIII | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·58 | 34·86 |

From these results the conclusion may be drawn that the low indications of the amount of permanganate apparently reduced during digestion in the experiments recorded in Table I, at least so far as concerns those experiments in which no ferric chloride was used, were in all probability due to the oxidizing action of the unexpelled chlorine on the oxalic acid, and that the large variations in results were due to the greater or less retention of the chlorine. In experiments XIII to XVIII it is seen further that amounts of permanganate very much greater than those used in Wagner's experiments and in the experiments of Table I above can be reduced by the same amount of hydrochloric acid, and under the same conditions of temperature and time as in those other experiments; for, in these last experiments, also, the permanganate color entirely disappeared during the digestion.

In order to ascertain if a current of air is equally as effective in removing the chlorine as is carbon dioxide, and also because of the greater availability of the former, the experiments recorded in Table III were conducted in a manner identical with those of Table II, except that a current of air dried and purified was substituted for the carbon dioxide. When also the success of the air current was apparent, ferric chloride was again used and the effect noted.

Results are outlined in the following table.

TABLE III.

[9·90$^{cm^3}$ approximately $\frac{N}{10}$ $H_2C_2O_4$ = 20·09$^{cm^3}$ $KMnO_4$.]

| | $\frac{N}{1}$ HCl $cm^3$. | $\frac{N}{10}$ HCl $cm^3$. | $\frac{N}{10}$ $FeCl_3$ $cm^3$. | $KMnO_4$ before digestion. $cm^3$. | Temperature. C°. | Time of digestion. min. | Residual $KMnO_4$ color after digestion. | Cl Test after digestion. | $H_2C_2O_4$ $cm^3$. | $KMnO_4$ to color. $cm^3$. | $KMnO$ apparently reduced during digestion. $cm^3$. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 100 | 9·90 | --- | 9·90 | 50 | 60 | none | none | 9·90 | 18·88 | 8·69 |
| II | 100 | 9·90 | --- | 9·90 | " | " | " | " | 9·90 | 18·87 | 8·68 |
| III | 100 | 9·90 | --- | 9·90 | " | " | " | " | 9·90 | 18·80 | 8·61 |
| IV | 100 | 9·90 | --- | 9·90 | " | " | " | " | 9·90 | 18·81 | 8·62 |
| V | 100 | 9·90 | --- | 9·90 | " | " | " | " | 9·90 | 18·80 | 8·61 |
| VI | 100 | 9·90 | --- | 9·90 | " | " | " | " | 9·90 | 18·82 | 8·63 |
| VII | 100 | 9·90 | --- | 9·90 | " | 30 | " | " | 9·90 | 18·77 | 8·58 |
| VIII | 100 | 9·90 | --- | 9·90 | " | " | " | doubtful | 9·90 | 18·70 | 8·51 |
| IX | 100 | 9·90 | --- | 9·90 | " | 15 | " | very faint | 9·90 | 18·70 | 8·51 |
| X | 100 | 9·90 | --- | 9·90 | " | " | " | " | 9·90 | 18·68 | 8·49 |
| XI | 100 | --- | 9·90 | 9·90 | " | 60 | " | none | 9·90 | 18·87 | 8·68 |
| XII | 100 | --- | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·85 | 8·66 |
| XIII | 100 | --- | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·81 | 8·62 |
| XIV | 100 | --- | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·81 | 8·62 |
| XV | 100 | --- | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·87 | 8·68 |
| XVI | 100 | --- | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·85 | 8·66 |
| XVII | 100 | --- | 9·90 | 9·90 | " | 30 | " | " | 9·90 | 18·80 | 8·61 |
| XVIII | 100 | --- | 9·90 | 9·90 | " | " | " | doubtful | 9·90 | 18·72 | 8·53 |
| XIX | 100 | --- | 9·90 | 9·90 | " | 15 | " | very faint | 9·90 | 18·65 | 8·46 |
| XX | 100 | --- | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·67 | 8·48 |

Here again may be noted the concordance of results when the chlorine is all removed before the addition of oxalic acid, as well as the fact that under these conditions substantially the same amount of permanganate is required to bring about the end reaction, whether ferric chloride is present or not; and that consequently as much permanganate is reduced during the digestion in the latter case as in the former. Also by a comparison of experiments VIII–X and XVIII–XX, in which a slight trace of chlorine remained, with experiments I–VI and XI–XVI, in which the chlorine was entirely removed, we again see the oxidizing effect of the residual chlorine on the oxalic acid; for even in the former sets of experiments, in which the digestion was carried on only fifteen or thirty minutes, the permanganate color had entirely disappeared at the end of the digestion. The variations in the amount of permanganate apparently reduced during the digestion in the experiments recorded in Table I are, therefore, doubtless due to the interfering action of the residual chlorine held in solution. The "$KMnO_4$ apparently reduced during digestion" in the experiments of Table II, and in those of Table III in which the chlorine was entirely removed during the digestion, represents the amounts of permanganate entirely reduced to manganous chloride, while the differences between these amounts and the "$KMnO_4$ before digestion" represent the residual oxides of manganese. Similar differences in the experiments of Table I, and in those of Table III in which the chlorine was only partially removed, represent the residual oxides of manganese and the chlorine retained in solution.

The amount of chlorine held in solution when no means are employed to remove it, depends largely on the form and size of the flask used to contain the solutions during digestion, also on the dimensions of the return-condenser, and will vary according to the greater or less amount of shaking to which the flask is subjected during the entire course of the experiment. It is, therefore, evident that Wagner's experiments are in no way indicative of the relative amounts of potassium permanganate reduced in the presence or absence of ferric chloride other conditions being constant, but are an indication simply of the greater or less retention of chlorine in solution in the form of apparatus used by him; for it has been shown that in all experiments conducted within the limits proposed by Wagner the permanganate is entirely destroyed and that any variations in the amount of permanganate apparently destroyed during digestion disappear when the chlorine is entirely removed from the sphere of action. The possibility of any interfering action of ferric chloride in titrations of oxalic acid by potassium permanganate is excluded by the results of the experiments of

Table III, in which we find no variations in results whether ferric chloride is present or not. The cause of the apparently greater destruction of potassium permanganate in those experiments of Table I in which ferric chloride was used than in those in which ferric chloride was not used, is now under investigation.

TABLE IV.

| | $\frac{N}{1}$ HCl cm³. | $\frac{N}{10}$ HCl cm³. | $KMnO_4$ before digestion. cm³. | $H_2O$ cm³. | Volume during digestion. cm³. | Temperature. C°. | Time of digestion min. | Residual $KMnO_4$ color after digestion. | Cl test after digestion. | $H_2C_2O_4$ cm³. | $KMnO_4$ to color. cm³. | $KMnO_4$ apparently reduced during digestion. cm³. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $[40^{cm^3}\ \frac{N}{10}\ (H_4N)_2C_2O_4 = 37{\cdot}64^{cm^3}\ KMnO_4$ | | | | | | | |
| | | | | | $100^{cm^3}\ H_2C_2O_4 = 101{\cdot}40^{cm^3}\ KMnO_4]$ | | | | | | | |
| I | 100 | 9·90 | 100 | -- | 210 | 50 | 60 | none | faint | 100 | 59·52 | 58·12 |
| II | 100 | 9·90 | 100 | -- | 210 | " | " | " | " | 100 | 58·44 | 57·04 |
| | | | | | $[40^{cm^3}\ \frac{N}{10}\ (H_4N)_2C_2O_4 = 18{\cdot}35^{cm^3}\ KMnO_4$ | | | | | | | |
| | | | | | $50^{cm^3}\ \frac{N}{5}\ H_2C_2O_4 \quad = 49{\cdot}26^{cm^3}\ KMnO_4.]$ | | | | | | | |
| III | 100 | 9·90 | 50 | -- | 160 | 50 | 60 | none | none | 50 | 30·72 | 31·46 |
| IV | 100 | 9·90 | 50 | -- | 160 | " | " | " | " | 50 | 30·75 | 31·49 |
| V | 100 | 9·90 | 50 | -- | 160 | " | " | " | " | 50 | 30·76 | 31·50 |
| VI | 100 | 9·90 | 50 | -- | 160 | " | " | " | " | 50 | 30·78 | 31·52 |
| VII | 100 | 9·90 | 50 | -- | 160 | " | " | " | " | 50 | 30·88 | 31·62 |
| VIII | 100 | 9·90 | 50 | 50 | 210 | " | " | faint | faint | 50 | 27·11 | 27·85 |
| IX | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 27·92 | 28·66 |
| X | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 28·52 | 29·26 |
| XI | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 28·54 | 29·28 |
| XII | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 29·14 | 29·88 |
| XIII | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 28·98 | 29·72 |
| XIV | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 28·56 | 29·30 |
| XV | 100 | 9·90 | 50 | 50 | 210 | " | " | " | " | 50 | 29·96 | 30·70 |
| XVI | 100 | 9·90 | 50 | 50 | 210 | " | 85 | none | very faint | 50 | 29·96 | 30·70 |
| XVII | 100 | 9·90 | 50 | 50 | 210 | " | 60 | faint | faint | 50 | 30·22 | 30·96 |
| XVIII | 100 | 9·90 | 75 | -- | 185 | " | " | none | marked | 50 | 20·72 | 46·46 |
| XIX | 100 | 9·90 | 50 | 50 | 210 | " | 120 | none | none | 50 | 30·31 | 31·05 |
| XX | 100 | 9·90 | 100 | -- | 210 | " | 60 | marked | marked | 60 | 19·58 | 60·47 |
| XXI | 100 | 9·90 | 75 | 50 | 235 | " | 220 | none | faint | 50 | 21·84 | 47·58 |
| XXII | 100 | 9·90 | 100 | 50 | 260 | " | 180 | marked | marked | 60 | 10·18 | 51·07 |
| | $\frac{2N}{1}$ HCl | | | | | | | | | | | |
| XXIII | 50 | 9·90 | 50 | -- | 110 | " | 60 | none | faint | 50 | 30·23 | 30·97 |
| XXIV | 50 | 9·90 | 75 | -- | 135 | " | 60 | " | marked | -- | -- | -- |
| XXV | 50 | 9·90 | 75 | -- | 135 | " | 60 | " | " | 50 | 30·69 | 56·43 |

Since in all experiments thus far conducted the permanganate color has been entirely destroyed, the experiments of Table IV

were made to ascertain if possible how much permanganate can be destroyed by the amount of hydrochloric acid used in the experiments of Table I, II, and III, under the same conditions of time and temperature, and also during greater periods of time. It will readily be seen from the evident oxidation of oxalic acid by chlorine in previous experiments that an exact measure of the maximum amount of permanganate reduction during a given period of time can be obtained only when all the chlorine is removed and at the same time the permanganate color just disappears—a condition difficult to attain. The results recorded in Table IV should therefore be regarded as approximate only.

Thus it may be seen that the same amount of hydrochloric acid as was used in the experiments of Table I, II, and III is capable of breaking down approximately thirty times as much permanganate as was used in those experiments and in the experiments of Wagner, conditions of time and temperature being the same. Changes of volume are of course involved in the use of varying amounts of permanganate but an increase in volume would in all probability be attended by a decrease in the relative amount of permanganate reduced by a constant quantity of hydrochloric acid. In any case the results show a more extensive reduction than is indicated in Wagner's experiments and in those of Tables I, II, and III above.

The conclusion must be drawn, then, that Wagner's experiments in no way show the catalytic effect of ferric chloride in the interaction between hydrochloric acid and potassium permanganate, nor do they furnish evidence in support of the assumed formation of chlor-ferrous acid. They afford simply an indication of the greater or less retention of chlorine in solution, and the greater or less oxidizing action of this chlorine on the oxalic acid in the presence or absence of ferric chloride.

The author is indebted to Prof. F. A. Gooch for much advice and assistance in the preparation of this paper.

ART. V.—*On Crystal Drawing;* by S. L. PENFIELD.

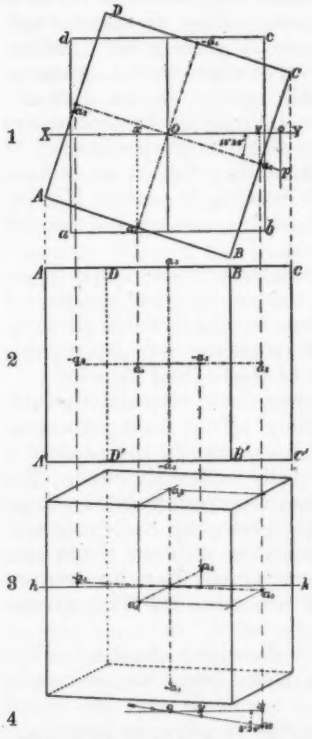
*Introduction.*—The methods commonly employed for representing crystals consist in drawing their edges as they appear when projected upon a plane. A peculiarity of the methods used is that the eye, or point of vision, is regarded as being at an infinite distance from the object, so that all edges which are parallel on a crystal appear as parallel lines in the drawing. Thus true perspective, whereby parallel edges would appear in a drawing as lines approaching one another in the distance, is lost sight of. Furthermore, two kinds of projection are employed: *orthographic*, where the lines of projection fall at right angles, and *clinographic*, where they fall at an oblique angle on the plane upon which the drawing is made. Most of the figures found in works on mineralogy and crystallography are drawn in clinographic projection.

The data generally employed in constructing a crystal figure are the inclinations and lengths of the axes and the symbols of the forms, while interfacial angles are not made use of directly, other than as they may have been employed for determiniug the axial relations and the symbols of the several faces.

To be really successful in drawing, it is essential that one should have a thorough understanding of the form or combination to be represented, and that every step in the process of constructing a figure should be fully comprehended. The reason for offering the present communication is the hope entertained by the writer, that by developing the subject of crystal drawing in a manner somewhat different from that generally adopted, the processes involved may be comprehended more readily and the work accomplished with greater facility and accuracy.

*Projection of the Axes of the Isometric System.*—It is believed that figures 1 to 4 will make clear the principles upon which the projection of the isometric axes are based. Figure 1 is an orthographic projection (a *plan*, as seen from above) of a cube in two positions, one, *a b c d*, in what may be called normal position, the other, *A B C D*, after a revolution of 18° 26′ about its vertical axis. The broken-dashed lines throughout represent the axes. Figure 2 is likewise an orthographic projection of a cube in the position *A B C D* of figure 1, when viewed from in front, the eye or point of vision being on a level with the crystal. In the position chosen, the apparent width of the side face *B C B′ C″* is one-third that of the front face *A B A′ B′*, this being dependent upon the angle of revolution 18° 26′, the tangent of which is equal to $\frac{1}{3}$. To

construct the angle 18° 26′, draw a perpendicular at any point on the horizontal line, as at *o* figure 1, make *op* equal one-third *Oo*, and join *O* and *p*. The next step in the construction is a change from orthographic to clinographic projection. In order to give figures the appearance of solidity it is supposed that the eye or point of vision is raised, so that one looks down at an angle upon a crystal which is figured; thus, in the case under consideration, figure 3, the top face of the cube comes into view. The position of the crystal, however, is not changed, and the plane upon which the projection is made remains vertical. From figure 1 it may be seen that the positive ends of the axes $a_1$ and $a_2$ are forward of the line $XY$, the distances $a_1\ x$ and $a_2\ y$ being as 3:1. In figure 2 it must be imagined, and by the aid of a model it may easily be seen, that the extremities of these same axes are to the front of an imaginary vertical plane (the projection of $XY$ above) passing through the center of the crystal, the distance being the same as $a_1\ x$ and $a_2\ y$ of the plan. In figure 4 the distance $ax$ is drawn of the same length as $a_1 x$ of the plan, and the amount to which it is supposed that the eye is raised, indicated by the arrow, is such that $a_1$ instead of being projected horizontally to $x$, is projected at an inclination of 9° 28′ from the horizontal to $w$, the distance $xw$ being one-sixth of $ax$; hence the angle 9° 28′ is such that its tangent is $\frac{1}{6}$.



FIGS. 1–4.—Development of the axes of the isometric system in orthographic and clinographic projection.

Looking down upon a solid at an angle, and still making the projection on a vertical plane, may be designated as *clinographic projection*; accordingly, to plot the axes of a cube in clinographic projection in conformity with figures 1, 2 and 4, draw the horizontal construction line *hk*, figure 3, and cross it by four perpendiculars in vertical alignment with the points $a_1$,—$a_1$ and $a_2$,—$a_2$ of figures 1 and 2. Then determine the

extremities of the first, $a_1$, $-a_1$ axis by laying off distances equal to $xw$ of figure 4, or one-sixth $a$, $x$ of figure 1, locating them below and above the horizontal line $hk$. The line $a_1$, $-a_1$ is thus the projection of the first, or front-to-back axis. In like manner determine the extremities of the second axis, $a_2$, $-a_2$, by laying off distances equal to one-third $xw$ of figure 4, or one-sixth $a_2$ $y$ of figure 1, plotted below and above the line $hk$. The line $a_2$, $-a_2$ is thus the projection of the second, or right-to-left axis. It is important to keep in mind that in clinographic projection there is no foreshortening of vertical distances. This is evident from figure 5, where $c$, $-c$ is supposed to represent a vertical axis and $XY$ the trace of a vertical plane on which the projection is made. The parallel lines of sight, indicated by the arrows, project the axis $c$, $-c$ to $c'$, $-c'$ without change of length. In figure 3 the axis $a_2$, $-a_2$ is somewhat, and $a_1$, $-a_1$ much foreshortened, yet both represent axes of the same length as the vertical, $a_3$, $-a_3$, and of the plan above, when plotted in clinographic projection. The completion of the cube about the clinographic axes, as indicated by the construction lines, figure 3, is too simple to need special comment.

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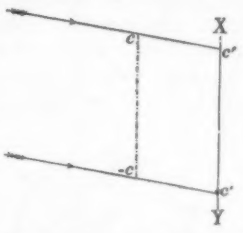


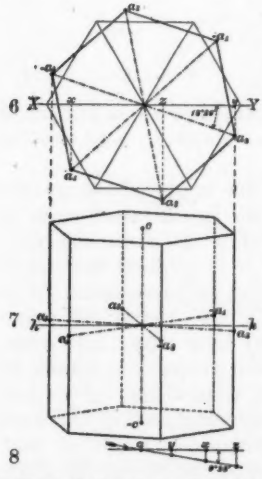

It is wholly a matter of choice that the angle of revolution shown in figure 1 is 18° 26′, and that the eye is raised so as to look down upon a crystal at an angle of 9° 28′ from the horizontal, as indicated by figure 4. Also it is evident that these angles may be varied to suit any special requirement. As a matter of fact, however, the angles 18° 26′ and 9° 28′ have been well chosen and are established by long usage, and practically all of the figures in clinographic projection, found in modern treatises on crystallography and mineralogy, have been drawn in accordance with them. The development of the axes as indicated by figures 1 to 4 yields the same result as that obtained from following the scheme found in almost all text-books of crystallography, accredited to Naumann.*

It will be observed that figures 1 and 3 are in vertical alignment, and one of the chief features of this communication will be to emphasize the value and importance of two projections, orthographic and clinographic. The object of the upper figure or *plan* is twofold: (1) it may be employed as a help in the construction of the more complex clinographic projection below, and (2) it serves to make clear certain relations which

* Lehrbuch der Krystallographie, 1830, Band II, p. 400.

at times are only with difficulty, if at all, comprehended from a clinographic projection alone. Figures 2 and 4 have been introduced merely as helps in the development of the clinographic projection. It is also worthy of note that in the majority of cases a plan and its accompanying clinographic projection may be drawn more readily than a single figure in clinographic projection alone.

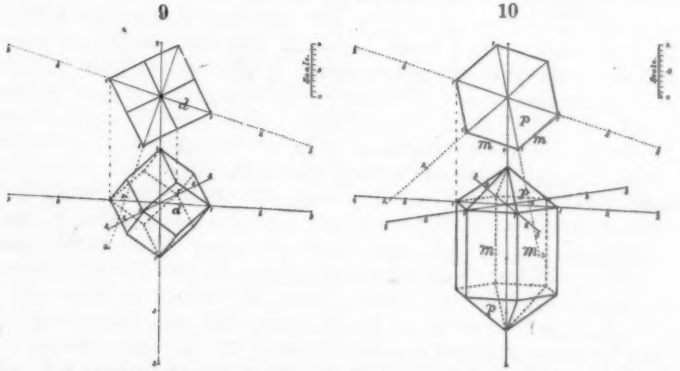
No originality is claimed for the idea of making use of a plan in connection with a clinographic projection. The principles are those commonly made use of in mechanical drawing, though generally in dealing with that subject orthographic projection alone is employed. In Kokscharow's Atlas accompanying his "Mineralogie Russlands" it will be found that a plan accompanies almost every figure drawn in clinographic projection, while Miller in his "Treatise on Mineralogy" employs orthographic projection almost exclusively. Lastly, students of crystallography may use an orthographic and its accompanying clinographic projection much as a carpenter or builder uses a plan and its accompanying elevation. The one supplements the other.




FIGS. 6, 7 and 8.—Development of the axes of the hexagonal system in orthographic and clinographic projection.

*Projection of the Axes of the Hexagonal System.*—For projecting the hexagonal axes exactly the same principles may be made use of as were employed in the construction of the isometric axes. Figure 6 is an orthographic projection, *a plan*, of a hexagonal prism in two positions, one of them, $a_1$, $a_2$, etc., after a revolution of 18° 26′ from what may be called normal position. In figure 7 the extremities of the horizontal axes of figure 6 have been projected down upon the horizontal construction line $hk$, and $a_1$, $a_2$ and $-a_3$ which are forward of the line $XY$ in figure 6 are located below the line $hk$ in the clinographic projection, the distances from $hk$ being one-sixth of $a_1x$, $a_2y$ and $-a_3z$ of figure 6. Figure 8 is a scheme for getting the distances which the extremities of the axes are dropped. The vertical axis in figure 7 has been given the same length as the axes of the plan.

*Engraved Axes.*—For the purpose of facilitating crystal drawing the writer has had the isometric and hexagonal axes engraved, and impressions of them made on good quality of drawing paper have been found very useful. To insure accuracy they were plotted on a large scale (the vertical axis 28$^{cm}$ in length) and they are shown very much reduced in figures 9 and 10. Each axis from the center is divided into thirds, and generally the lengths marked 1, when taken as *unity*, will give a figure of convenient size for drawing. In figure 9 an orthographic and a clinographic projection of a dodecahedron are shown, and in figure 10 corresponding projections of a combination of prism *m* and pyramid *p* of apatite, $c = 0{\cdot}735$. As is evident from the figures, the upper axes are for orthographic,




FIGS. 9 and 10.—Scheme of the engraved axes of the isometric and hexagonal systems, one-sixth natural size.

the lower for clinographic projections. The sections of the axes marked *2* and *3* are lengths most frequently needed in the construction of complex figures. Printed on each sheet is a scale which will be referred to as the *scale of decimal parts*. Its length is equal to that of *unity* on both the vertical axis and the axes for orthographic projection. As printed on the original sheets the scale is divided into one hundred parts.

*Axes of the Tetragonal and Orthorhombic Systems.*—For drawing tetragonal and orthorhombic crystals the engraved isometric axes may be used, after changing certain lengths. The vertical axis for both systems is changed by taking the desired length from the scale of decimal parts, referred to in the previous paragraph. For an orthorhombic crystal the length of the brachy, or $\breve{a}$, axis is first laid off on the front-to-

back axis of the orthographic projection above by means of the scale of decimal parts, and is then projected down upon the front-to-back axis below by means of a vertical line. Thus with facility and accuracy the engraved isometric axes may be modified to suit the requirements of any tetragonal or orthorhombic crystal.

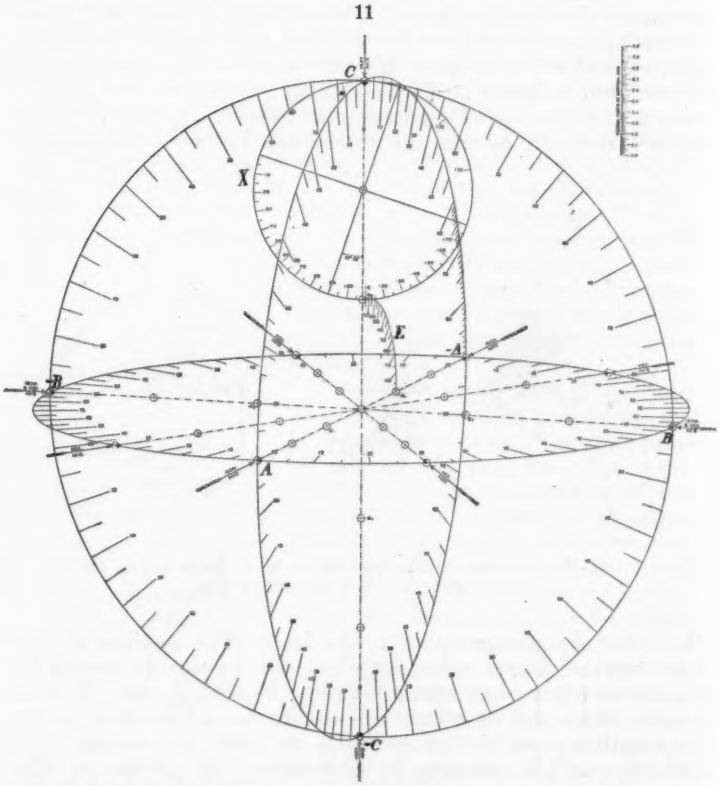



FIG. 11.—Protractor for plotting crystallographic axes; one-third natural size.

*Projection of the Axes of the Monoclinic and Triclinic Systems.*—These axes are obtained from those of the isometric system by giving the lines suitable inclinations, and varying their lengths. Instead, however, of using the methods generally employed for inclining the axes, it occurred to the writer

that both time and accuracy might be gained by constructing a suitable protractor, which is shown one-third its natural size in figure 11. At the top is a graduated circle, *X*, two of the diameters of which inclined at 18° 26′ to the vertical and horizontal, represent unit lengths of the *a* and *b* axes in orthographic projection. The uses of the circle and its graduation will be explained later. The three large ellipses are the clinographic projections of three circles uniting the ends of the isometric *A*, $-A$; *B*, $-B$ and *C*, $-C$ axes; they represent, therefore, the paths which the extremities of the axes would follow if the latter were revolved in the three axial planes. The ellipses may also be regarded as the clinographic projection of three great circles of a sphere; an equator, crossed by two meridians at 90° to one another. The ellipses and their graduation were plotted with much care, and the engraving was skillfully executed by Messrs. Bormay & Co. of New York. Each axis is divided into thirds, and a scale giving decimal parts of the vertical axis accompanies the protractor. The quadrant of a small ellipse *E* has a radius equal to one-third that of the large ellipse. It is intended for getting one-third the length of an inclined *a* axis, but it has not proved to be of much value. Printed on cardboard, the protractor may be used for a long time, it being intended that the axes shall be transferred to a sheet of drawing paper by superimposing the protractor and puncturing the unit lengths of the axes with a needle point.

The axial protractor has been in use in the writer's laboratory for four years, and has been found very convenient, not only for plotting axes of the monoclinic and triclinic systems, but, also, for constructing the axes of twin crystals. It may be said of the protractor and also of the engraved axes that they have proved to be not only time-savers, but they have also helped to make the work of crystal drawing more accurate and better understood. Students frequently encounter difficulties in crystal drawing because the axes with which they are working have not been plotted with accuracy, but by the use of the engraved axes this difficulty, at least, is eliminated.

A few examples will serve to illustrate the methods of using the axial protractor in plotting inclined axes.

In both the monoclinic and triclinic systems the same method is used for plotting the *a* axis at the inclination $\beta$, hence one example in the triclinic system will serve for the two classes of crystals. The example chosen is rhodonite, and the data needed are as follows:

$$a : b : c = 1{\cdot}073 : 1 : 0{\cdot}621$$
$$\alpha = 103° 18′; \quad \beta = 108° 44′.$$
$$a \wedge b,\ 100 \wedge 010 = 94° 26′.$$

The projection of the *a* axis, which is the same for both the monoclinic and triclinic systems, will first be explained: When *a* is not at right angles to *c*, it must appear somewhat foreshortened in orthographic projection, as shown in figure 12, which represents the relations of the *a* and *c* axes of rhodonite: *XY* being the trace of the horizontal plane on which the orthographic projection is made, the *a* axis, length 1·073, will appear foreshortened to the length *Oa′*. Applying the foregoing principle to the upper circle of the protractor, figure 13, draw a radius at the inclination $\beta$, 108° 44′, making use of the graduation of the circle, lay off on this

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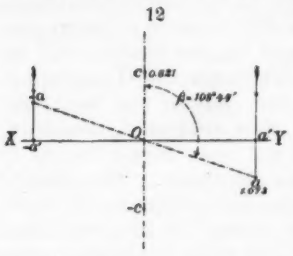

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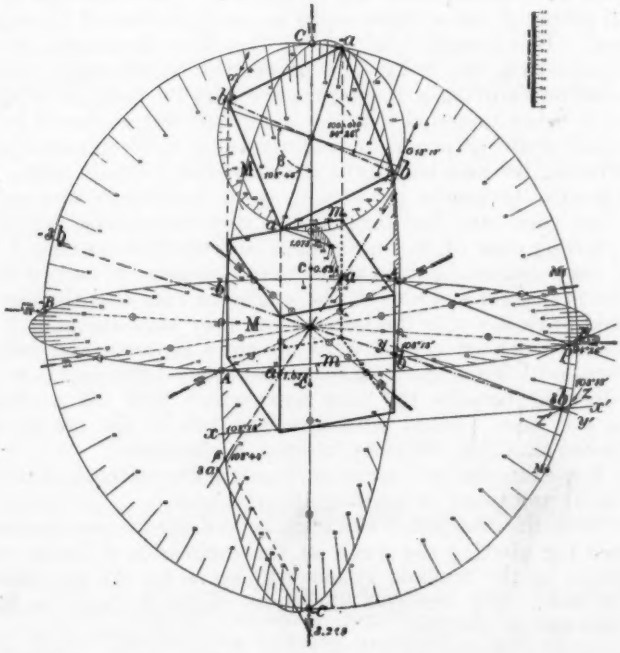

radius the length of the *a* axis (1·073 in figure 13) using the scale of decimal parts, and then project at right angles to the direction *a*, $-a$, as indicated by the arrow, thus determining

the length of the foreshortened $a$ axis. For the clinographic projection locate $\beta$, 108° 44′, on the graduation of the ellipse passing through $A$ and $C$, draw a diameter through the center and fix the length of $a$ by projecting down vertically from $a$ of the orthographic axis above. If one does not wish to make use of the orthographic axes, draw the diameter of the ellipse at the inclination $\beta$, and find the length $3a$ by laying off a distance equal to $3a$ on the vertical axis (3·219 in figure 13), using the scale of decimal parts, and then transpose the length thus found to the inclined $a$ axis by drawing a line parallel to $\beta$, $-C$, as shown in the figure: One-third of the length thus determined is the desired length of the $a$ axis.

Two processes are involved in plotting the $b$ axis of a triclinic crystal. (1) The vertical plane in which the $b$ and $c$ axes are located is revolved about the $c$ axis so as to conform to the measurement $a \wedge b$, $100 \wedge 010$. Care must be taken to note the direction in which the plane of the $b$ and $c$ axes is turned: (1) As shown in figure 14, since $100 \wedge 010$ (angle between normals) is 94° 26′ in rhodonite, the right-hand end of the $b$ axis is first swung forward 4° 26′ in the plane of the equator. Carrying out the foregoing process in figure 13, a point $p$ is located on the equator, 94° 26′, measured from $-A$, and likewise $b$ of the orthographic projection above is brought forward to a position 94° 26′ from $-a$. (2) The horizontal $b$ axis, in its new position, must next be inclined to the vertical axis at the angle $a$, which in rhodonite is 103° 18′. For the orthographic projection above, this inclination of the $b$ axis causes some foreshortening, which is determined by laying off two points $o$ and $o'$, figure 13, 13° 18′ (103° 18′ −90°) on either side of where the $b$ axis intersects the divided circle, and projecting through the points thus formed at right angles to the direction $b$, $-b$, as indicated by the arrows. To give the $b$ axis of the clinographic projection its proper inclination, the value of $a$, 103° 18′, is laid off on two, or preferably three, of the vertical ellipses, as at $x$, $y$ and $z$, figure 13, measured from $C$. Next draw three chords, $Ap$, $-Ap$ and $Bp$, on the plane of the equator, and parallel to them, respectively, the chords $xx'$, $yy'$ and $zz'$. The common intersection of the three chords determine a point $3b$, on the surface of an imaginary sphere and on a meridian $Me$ passing through $p$. The point $3b$ is 13° 18′ below the equator and 103° 18′, that is $a$, from $C$. A line from $3b$ through the center is the projection of the $b$ axis, and a perpendicular from

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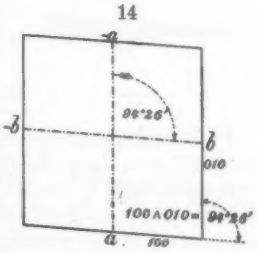

*b* of the orthographic projection above will intersect the axis at one-third of its length.

The principle involved in the projection of the clinographic *b* axis, as given above, is very simple. Imagine a sphere with two points fixed on its equator corresponding to *A* and *p* of figure 13, and then a chord *Ap* through the two points; it then follows that a series of chords parallel to *Ap* drawn through the 5°, 10°, 15°, etc., graduation points of the meridian through *A* would all emerge from the imaginary sphere on a meridian *Me*, figure 13, passing through *p*, at points 5°, 10°, 15°, etc., from the equator. By drawing two chords, $xx'$ and $yy'$, as in figure 13, or a third $zz'$ so as to make more certain of the intersection, any desired point on the meridian through *p* is quickly found. In figure 13 a combination of the prisms *m* (110) and *M* ($1\bar{1}0$) and the base *c* (001) has been drawn.

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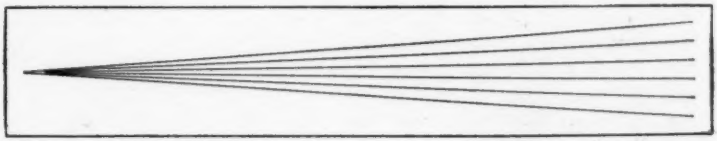

It may be said concerning the protractor that it has been plotted on a large scale to insure accuracy, and that lengths corresponding to one-third those of the axes will generally be found convenient for drawing simple crystal figures. In connection with the protractor it is recommended to use a scale, corresponding to figure 15, printed or drawn on tracing cloth or paper. When the outer lines of such a scale are adjusted between the five degree graduation marks of the ellipses, the intermediate lines will serve to subdivide the space into fifths, or degrees.

*Projection of the Axes of twinned Crystals.*—The axial protractor furnishes a ready means for plotting the axes of twin crystals, a problem which at times presents considerable difficulty, especially to beginners, hence two examples may be cited explaining the uses of the protractor. In staurolite, twins according to a pyramid are common, and in the example chosen it will be assumed that a face having the symbol $\bar{2}3\bar{2}$ ($-\frac{2}{3}a : b : -\frac{2}{3}c$) is the twinning plane. The data employed in plotting the axes are the axial lengths, $a : b : c = 0{\cdot}473 : 1 : 0{\cdot}683$, and the $\phi$ and $\rho$ angles of the twinning plane; $\phi = 010 \wedge \bar{2}30 = 54°\ 37'$ and $\rho = 00\bar{1} \wedge \bar{2}3\bar{2} = 60°\ 31'$. To insure accuracy in plotting, the full lengths of the axes of the protractor have been regarded as unity. In figure 16 the axial lengths $-a$ and

$-\frac{3}{2}a$ ; $b$ ; and $-c$, and $-\frac{3}{2}c$ are laid off both on the orthographic and clinographic projections of the axes, and the twinning plane $-\frac{3}{2}a : b : -\frac{3}{2}c$ drawn. The value of $\phi$, 54° 37′, is laid off at $p$ on the equator, measuriug in the direction of the arrow from $b$, and the radius from the center $O$ to $p$ makes an angle of 90° at $P'$ with the line $-\frac{3}{2}a : b$. The twinning axis, a line

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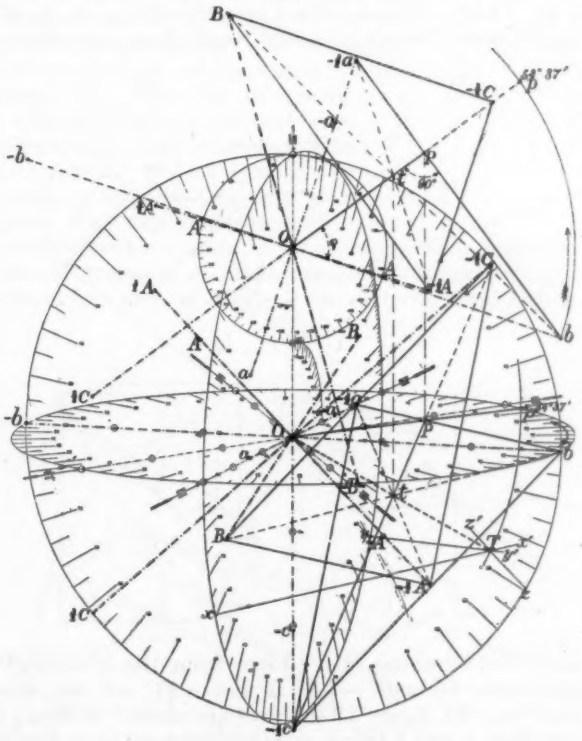


from the centre at right angles to the twinning plane, is now plotted on the clinographic axes by finding a point $T$, on the meridian through $p$, 60° 31′ (the value of $\rho$) from the south pole of an imaginary sphere. This is done by locating $x$, $y$ and $z$ on the graduated ellipses at 60° 31′ from the south pole, and drawing the chords $xx'$, $yy'$ and $zz'$ parallel, respectively, to chords on the plane of the equator through $p$ and the intersections of the $a$ and $b$ axes with the equator. The intersection of the three chords determine the desired point $T$ at the

surface of an imaginary sphere on the meridian through $p$, and $OT$ is the twinning axis. The point $t$, where the twinning axis pierces the twinning plane, is determined by the intersection of the twinning axis $OT$ with a line drawn from $-\frac{3}{2}c$ to $P$. The points $p$, $P$ and $t$ of the orthographic projection are in vertical alignment with corresponding points on the lower axes, and need no further explanation. Having found $t$ on both the clinographic and orthographic axes, the ends of the axes, $-\frac{3}{2}a$, $b$ and $-\frac{3}{2}c$, are shifted respectively to $-\frac{3}{2}A$, $B$ and $-\frac{3}{2}C$, equidistant from $t$, as would result from a revolution of

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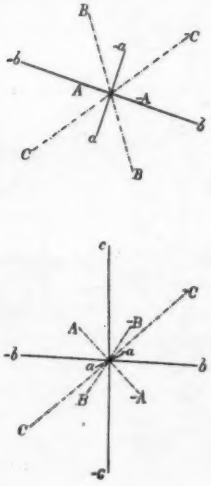


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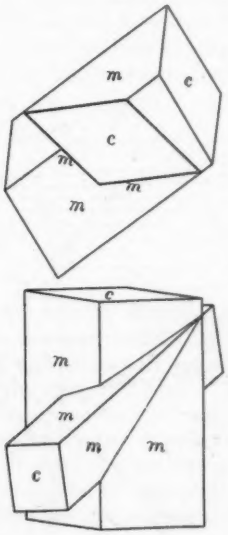


180° about the twinning axis. Lines from the centers of the two projections through $-\frac{3}{2}A$, $B$ and $-\frac{3}{2}C$ are the axes in twin position. In figure 17 the axes are shown without construction lines, $a$ and $b$ being one-third as long as in figure 16, and in figure 18 two projections of interpenetrating prisms, $m$, terminated by basal planes, $c$, are shown.

A problem encountered by W. E. Ford and the writer in the study of twin crystals of calcite from Union Springs, N. Y.,* may be cited as a second example for illustrating the uses of the axial protractor in plotting the axes of twin crystals. It was desired to represent a scalenohedron, twinned about the rhombohedron $f$ $(02\bar{2}1)$, so drawn that the

* This Journal (4), x, p. 237, 1900.

twinning plane should be vertical and have the position corresponding to that of the side pinacoid $b$ (010) of an orthorhombic crystal. The solution depends upon the angle of base on twinning plane, $c \wedge f = 63° 7'$, from which the inclination of the vertical axes, 53° 46′ from one another, or 26° 53′ from the twinning plane placed in vertical position, as shown in figure 19, is derived. As indicated by figure 20, the inclinations of the vertical axes, $c$ and $C$, 26° 53′, from the perpendicular, are determined by the graduation of the vertical ellipse through $B$. Also the intersections of the planes of the horizontal axes with the same ellipse are located at $X$ and $X'$, and $Y$ and $Y'$, 26° 53′ from $B$ and $-B$. In order to have the twinning plane correspond with the side pinacoid 010 of the orthorhombic system, it is necessary to make one of the horizontal axes $-a_1$, $a_2$ of the hexagonal system correspond with the front and back or $a$ axis of the orthorhombic system. The

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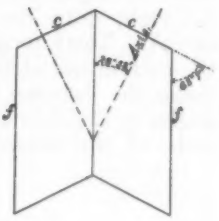

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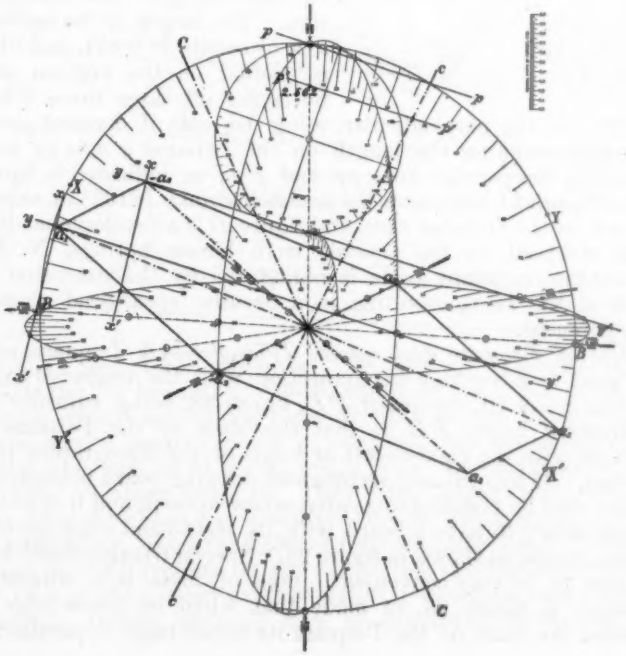

other hexagonal axes, therefore, must intersect great circles passing through $-a_3$ and $X$, and $-a_3$ and $Y$, at 60° from $-a_3$ and $a_3$. To find the desired intersections on the great circle at right angles to one of the twinned axes, $c$; through the 60° graduation points on the horizontal ellipse to the left, figure 20, draw the chords $xx'$ parallel to a chord through $-B$ and $X$; likewise through the 60° points on the horizontal ellipse to the right draw the chords $yy'$ parallel to a chord through $B$ and $X$. The intersections of the chords $xx'$ and $yy'$ determine the extremities of the horizontal axes $a_1$, $-a_1$, and $a_2$, $-a_2$. To make the drawing somewhat more real, a hexagon at right angles to the twin axis $cc$ has been constructed, by uniting the ends of the horizontal axes. Following a similar process (drawing chords parallel to $BY$ and $-BY$ through the 60° graduation points of the horizontal ellipse) the extremities of the horizontal axes at right angles to the twinned axis $C$ would be found, but it has not seemed best to complicate the figure by carrying out this construction. The length of the vertical axis of calcite is 0·854, and this is plotted on the vertical axis by laying off three times 0·854 (2·562) on the perpendicular, using the scale of decimal parts, and proportioning the length on the twinned $c$ axis by constructing the parallel lines $pp$ and $p'p'$, as indicated in figure 20. Figure 21 represents the scalenohedron $v$ $\{21\bar{3}1\}$ of calcite drawn on the twinned axes, and figure 22 is a development like that observed on the crystals from Union Springs, N. Y., where the re-entrant angle is obliterated by the extension of four of the faces, resulting in a peculiar spear-head shaped development.

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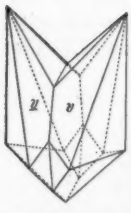


22

*Use of T-square and special Triangles.*—A T-square may be used to advantage in connection with the engraved axes, figures 9 and 10, the paper $PP$, figure 23, being adjusted on a drawing board $BB$ so that the blade of the T-square is parallel with the right-to-left or $b$ axis of the clinographic projection. If an ordinary rectangular drawing board is used, the paper may be fastened somewhat askew upon it, and it is not at all necessary to have a board with its right-hand edge cut at a special angle, as shown in figure 23. Special triangles have also proved to be very convenient. One of these is a truncated triangle $I$, figure 23, so made that when its lower edge is against the blade of the T-square its upper edge is parallel to

the right-to-left of *b* axis, and its left-hand edge parallel to the front-to-back or *a* axis of the orthographic projection. A second triangle *II* is shown in two positions in figure 23; II*a*, when its shorter edge is against the blade of the T-square its right-hand edge is parallel to the vertical axis, and, II*b*, when one of its longer edges is against the blade of the T-square its upper edge is parallel to the front-to-back or *a* axis

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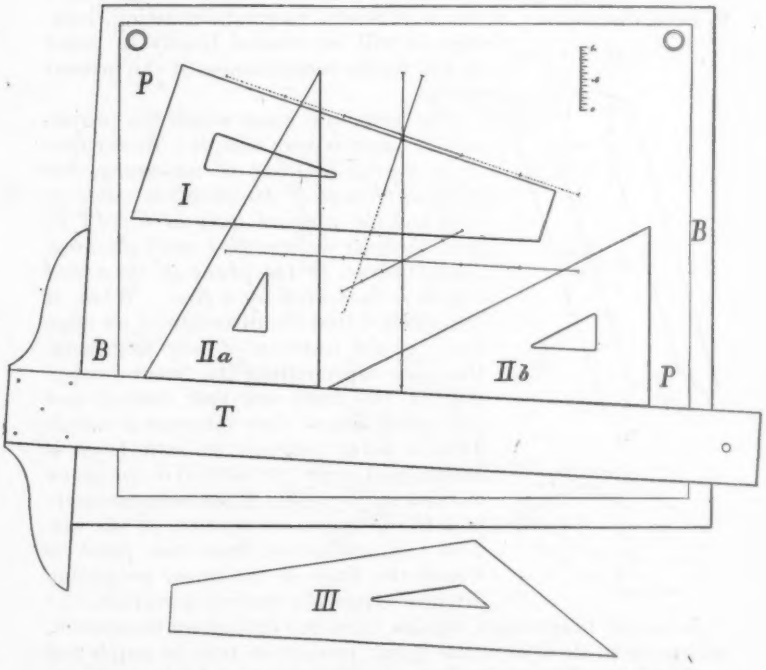
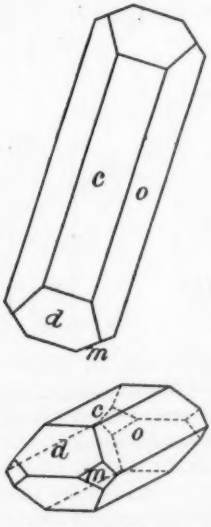



of the clinographic projection. A third triangle *III*, figure 23, is for the hexagonal system, and is so made that when its longer edge is against the blade of the T-square its upper left-hand edge is parallel to the $a_1$, $-a_1$ axis, and its upper right-hand edge parallel to the $a_2$, $-a_2$ axis of the clinographic projection; compare figure 10. Thus with T-square and triangles, the axial directions, the essential ones in the construction of a crystal figure, may be had almost instantly, excepting, of course, some of the directions of the monoclinic and triclinic systems.

*Uses of the Linear or Quendstedt Projection.*—In drawing crystals various methods may be employed for finding the

direction of an edge made by the meeting of any two faces, but the principle depends generally upon locating two points, common to both faces, where they intersect certain axial planes. A line through the points thus found gives the direction of the edge. In general it will be found best to adopt some system for determining the direction of crystal edges, and to adhere to it rather strictly, and the writer has found the method based upon the linear or Quenstedt projection most useful. The projection is too well known to crystallographers to need discussion; as far as it relates to crystal drawing, however, it will be treated briefly in order to add to the completeness of the present article.

24




The principle upon which the projection is based is very simple: *Every face of a crystal (shifted if necessary, but without change of direction) is made to intersect the vertical axis at UNITY, and then its intersection with the horizontal plane, or the plane of the a and b axis is indicated by a line.* When it is desired to find the direction of an edge made by the meeting of any two faces, the lines representing the linear projection of the faces are first drawn, and the point where they intersect is noted. Thus a point common to both faces is determined, which is located in the plane of the *a* and *b* axes. A second point common to the two faces is *unity* on the vertical axis, and a line from this point to where the lines of the linear projection intersect gives the desired direction.

A simple illustration, chosen from the orthorhombic system, will serve to show how the linear projection may be employed in drawing. The example is a combination of barite, such as is shown in figure 24. The axial ratio of barite is as follows:

$$a : b : c = 0{\cdot}8152 : 1 : 1{\cdot}3136$$

The forms shown in the figure and the symbols are, base *c* (001), prism *m* (110), brachydome *o* (011) and macrodome *d* (102).

Figure 25 represents the details of construction of the orthographic and clinographic projections shown in figure 24. On the orthographic axes the axial lengths *a* and *b* are located, the vertical axis *c* being foreshortened to a point at the center. On the clinographic axes, centered at *O*, the ends of the axes *a* and *b* are located by dropping perpendiculars from corre-

sponding points above, and the length of the vertical axis 1·316 is laid off above and below *O* by means of the scale of decimal parts, at points marked *1* and *−1* in the figure. The lines of the linear projection needed for the two sets of axes are as follows: For the brachydome *o*, 011, the lines *xz* and *x′z′*, through *b* parallel to the *a* axis: For the macrodome *d*, 102 (2*a* : ∞*b* : *c*), the lines *xy* and *x′y′*, through 2*a* parallel to the *b* axis: The prism *m* (110) is parallel to the vertical axis,

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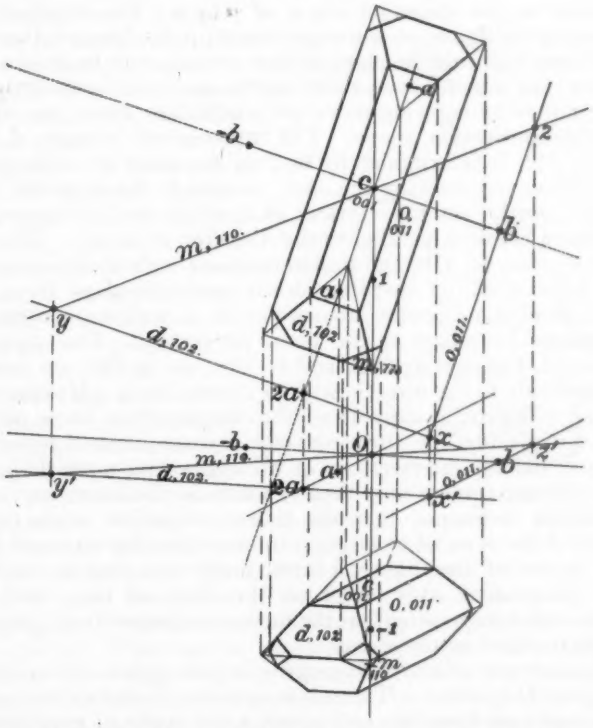


hence in order that such a plane shall satisfy the conditions of the linear projection and pass through *unity on the vertical axis*, it must be considered as shifted (without change of direction) until it passes through the center: Its linear projection therefore is represented by the lines *yz* and *y′z′*, parallel to the directions *a* to *b* on the two sets of axes. Since a linear projection is made on the plane of the *a* and *b* axes, the intersection of any face with the base (001) has the same direction as

the line representing its linear projection. It is well to note that the intersections $x$, $y$ and $z$ and $x'$, $y'$ and $z'$ are in vertical alignment with one another.

Concerning the drawing of figure 25, it is a simple matter to proportion the general outline of the barite crystal in orthographic projection. The direction of the edge between *d*, 102, and *o*, 011, is determined by finding the point $x$, where the lines of the linear projection of *d* and *o* intersect, and drawing the edge parallel to the direction from $x$ to the center *c*. The intersection of the prism *m*, 110, with *d* and *o* is a straight line, parallel to the direction *a* to *b* or *y* to *z*. To construct the clinographic figure, at some convenient point beneath the axes the horizontal middle edges of the crystal may be drawn parallel to the *a* and *b* axes, their lengths and intersections being determined by carrying down perpendiculars from the orthographic projection above. The intersection between *d*, 102, and *o*, 011, is determined by finding the point $x'$ of the linear projection and drawing the edge parallel to the direction from $x'$ to 1 (*unity*) on the vertical axis, while the corresponding direction below is parallel to the direction $x'$ to $-1$. The size of the prism *m*, 110, and its intersections with *d* and *o* may all be determined by carrying down perpendiculars from the orthographic projection above, but it is well to control the directions by means of the linear projection: The edges between *m*, 110, and *d*, 102; and *m*, 110, and *o*, 011, are parallel respectively to the directions $y'$ to *1* and $z'$ to *1*. Having completed a figure, a copy free from construction lines may be had by placing the drawing over a clean sheet of paper and puncturing the intersections of all edges with a needle-point: An accurate tracing may then be made on the lower paper.

Should it happen that the linear projection made on the plane of the *a* and *b* axes gives intersections far removed from the center of the figure, a linear projection may be made on the clinographic axes either on the plane of the *a* and *c* or *b* and *c* axes, supposing that the faces pass, respectively, through *unity* on the *b* or the *a* axes.

*Importance of an Orthographic in connection with a Clinographic Projection.*—There is no question in the writer's mind that many students, on commencing the study of crystallography, fail to derive the benefit they should from the figures given in text-books. Generally clinographic projections are given almost exclusively, with perhaps occasional basal or orthographic projections, and beginners find it hard to reconcile many of the figures with the appearance of the models and crystals which they are intended to represent. For example, given only the clinographic projection of barite, figure 24, it takes considerable training and knowledge of the projection

employed to gain from the figure a correct idea of the proportions of the crystal which it actually represents. This may be shown by comparing figures 24 and 26, which represent the same crystal, drawn one with the *a*, the other with the *b* axis to the front. It is seen from figure 26 that the crystal is far longer in the direction of the *a* axis than one would imagine from inspection of only the clinographic projection of figure 24. The front or *a* axis is much foreshortened in clinographic projection, consequently by the use of only this one kind of projection there is a two-fold tendency to err; on the one hand, in drawing, one is inclined to represent those edges running parallel to the *a* axis by lines which are considerably too long, while, on the other hand, in studying figures there is a tendency to regard them as representing crystals which are too much compressed in the direction of the *a* axis. By using orthographic in connection with clinographic projections these tendencies are overcome. Having in mind the proportions of a certain crystal, or having at hand a model, it is easy to construct an orthographic projection in which the *a* and *b* axes are represented with their true proportions; then the construction of a clinographic projection of correct proportions follows as a comparatively simple matter. Without an orthographic projection it would have been a difficult task to have constructed the clinographic projection of figure 26 with the proportions of the *a* and *b* axes the same as in figure 24, while with the orthographic projection orientated as in figure 26 it was an easy matter. Then again, given a model for study, say of barite corresponding to figure 24, a student holding the model properly orientated, over or near to the orthographic projection, and looking down on it from above, sees at once the relations between the model and the figure: Prismatic angles have their true value in the drawing, and the directions and relative lengths of all of the edges appear to be the same as on the model. From an orthographic projection alone, however, one can gain no conception of the length of a crystal in the direction of the vertical axis, nor of the steepness of its terminal faces: A combination of two projections is needed, and from two figures a proper conception of the development

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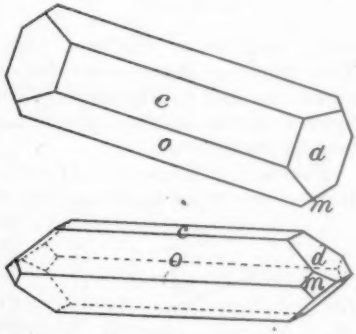

of a crystal may be had. Without question, in many and perhaps the majority of cases, figures in orthographic projection would be far more helpful to beginners, especially if studied in connection with models, than the ones so commonly used which are in clinographic projection alone. An architect in working out the details for any structure would never think of

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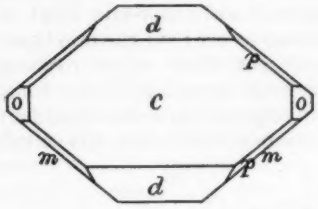


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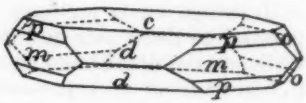


submitting to a builder a plan alone, or only an elevation: Two kinds of figures are considered as necessary, plans and elevations, and in like manner students of crystallography need figures drawn in two projections in order to derive the full benefit from them.

*Position of Figures.*—If orthographic and clinographic projections are to be used together there is some choice as to the position in which the figures should be placed. Taking barite as an example: If an orthographic projection alone were employed there is no question but that the drawing should be orientated as in figure 27, with the direction of the *a* and *b* axes parallel respectively to the vertical and horizontal edges of the page. Provided two projections are used, however, if the clinographic, figure 28, is placed to one side of the orthographic, or directly below it, the apparent connection between the two figures is not at all evident: To place them thus is in violation of the principles of mechanical drawing and projection, and it is hard to realize that figures 27 and 28 are representations of the same crystal. Placed as in figure 29, however, it takes but little study to understand how the two projections are related. It is true that it may at first seem strange to see the orthographic projections skewed around at

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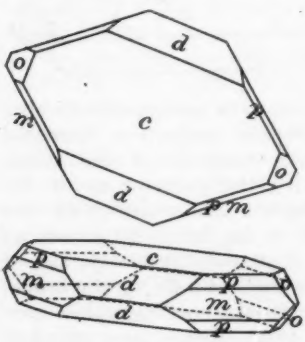
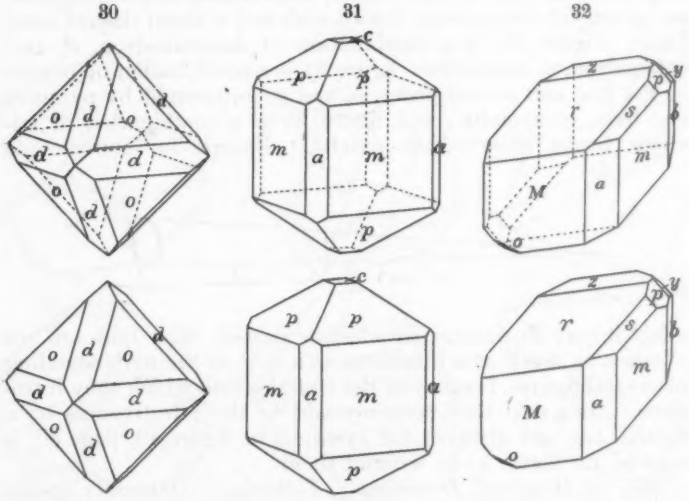


an angle of 18° 26′, but this is a condition to which one would soon become accustomed. If orthographic and clinographic projections are to be used together for purposes of illustration, it is believed that the orthographic projections should be left in the position in which they were drawn, and printed as in figure 29, although this is a matter which need not be insisted upon.

*Stereoscopic Effect.*—It has frequently been observed that the figures in text-books do not convey to many students the impression of solidity, and this is a defect which probably has




been generally recognized. Some have sought to overcome the difficulty by making use of two projections drawn at slightly different angles, as a crystal would appear if seen from the positions of the right and left eyes, and then viewing the two pictures with a stereoscope. The effects produced are most satisfactory, but for purposes of text-book illustration and for class-room work the method is scarcely practical. If a clinographic projection is well drawn, with the front edges represented by full lines and the back edges by somewhat lighter, dashed lines, a very satisfactory and at times quite remarkable stereoscopic effect may be had by viewing the figure through a tube. The practice is one commonly employed by artists in studying effects. The tube may be a roll of light or dark paper, either cylindrical or conical, quite variable in size (6$^{cm}$ long by 1$^{cm}$ diameter gives good results), while the most convenient thing to use is one's hand, doubled up so as

to form a sort of tube. Stereoscopic effects are more pronounced with some figures than with others, but they would seem to depend to a large extent upon the proper proportioning of the heavier front and lighter (dashed) back lines. It is believed that the reason for the stereoscopic effect is not far to seek;—it seems to be wholly an optical illusion.—By looking through a tube the attention is concentrated on a single figure, and the heavy lines produce the effect of being near, the fainter, dashed lines of being farther away; hence the conception of solidity. In order that the stereoscopic effect may be observed by the reader, illustrations of three crystals are given for comparison, drawn with and without dashed back lines; Figure 30 is a combination of dodecahedron, *d*, and octahedron, *o*, magnetite; figure 31 is a combination of prisms of the first and second order, *m* and *a*, terminated by pyramid and base, vesuvianite; and figure 32 is a combination of triclinic forms observed on axinite. Except for stereoscopic

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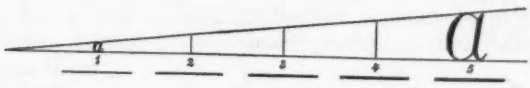


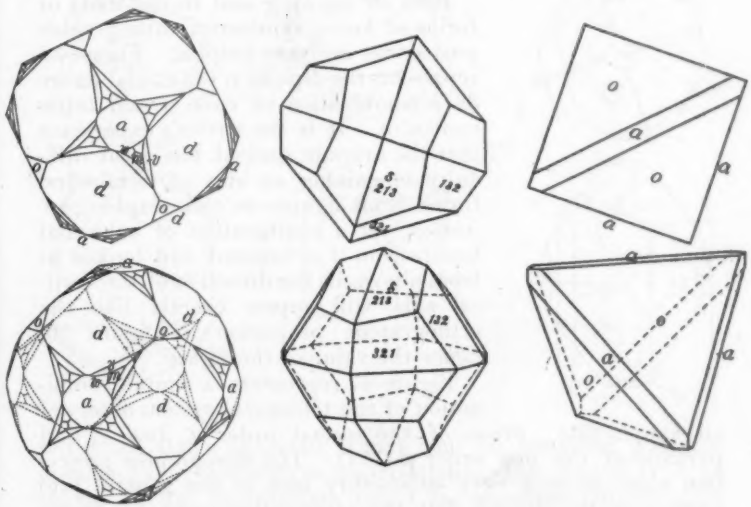

effect it may be questioned whether dashed back lines are not at times as much of a hindrance as a help in the understanding of crystal figures, because of the complexities which they introduce. As a rule they certainly add to the effectiveness of a figure, but not always; for example, in figure 18, page 50, it seemed far better to do without them.

*Size of Original Drawings; Lettering.*—Generally speaking, the size of an original drawing should depend to a large extent upon the complexity of the figure. It may be recommended to draw simple figures three or four times as large as needed for illustration, while with a complex subject like figure 34 it is almost impossible to make a drawing with accuracy except on a scale seven or eight times the size of the illustration. Figure 34 represents a crystal with 240 edges; hence it is evident that it is necessary to make the original drawing on a large scale in order to preserve with accuracy the directions of the many short lines.

If figures are to be reduced by the photo-engraving process, they must be drawn in ink and lettered to suit the reduction. Figure 33 gives the approximate width of line and size of letter to be used with various degrees of reduction indicated by the numbers. Almost any one can succeed fairly well in forming letters who will take pains and make use of good models.

*Uniformity of Lettering.*—A gain has been made in recent years in adopting some uniformity in lettering, as must be appreciated by all who are accustomed to use Dana's System of Mineralogy. The scheme there adopted is in general to indicate the three pinacoids, 100, 010 and 001, by *a*, *b* and *c*, respectively, and the prism 110 by *m*. In the hexagonal and rhombohedral systems the prisms of the first and second orders are designated by *m* and *a*, respectively, in conformity with the usages of the tetragonal system, and the unit rhombohedron is designated by *r*. In the isometric system the cube, octahedron and dodecahedron are lettered *a*, *o* and *d*, respec-

34 35 36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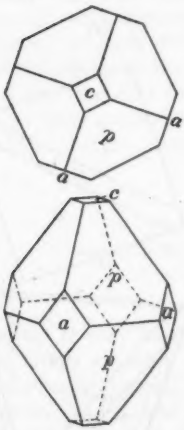
For the normal group of the isometric system, the forms observed on a specimen of magnetite in the Brush Collection, from Achmatowsk, Ural Mts., figure 34, has been chosen. The figure was drawn by Mr. R. G. Van Name when a student in the writer's laboratory. The combination is unusually complex, trapezohedron *m* (311) and two hexoctahedrons, *v* (531) and *w* (21 . 7 . 5), besides the simple forms *a*, *o* and *d*. A similar combination, but with somewhat different development of the forms, is described by Kokscharow.* In the construction of the complex clinographic figure, the orthographic projection proved to be a great help.

37




Both in drawing and in the study of forms of lower symmetry, orthographic projections are very helpful. Figure 35 represents the diploid *s*, (321), and figure 36 a combination of cube *a* and tetrahedron *o*. It is the writer's experience that the average student has great difficulty in gaining an idea of tetrahedral forms from figures in clinographic projection, yet a combination of cube and tetrahedron if orientated and looked at from above, in the direction of the vertical axis, will appear exactly like the orthographic projection of figure 36, hence the value of the figure.

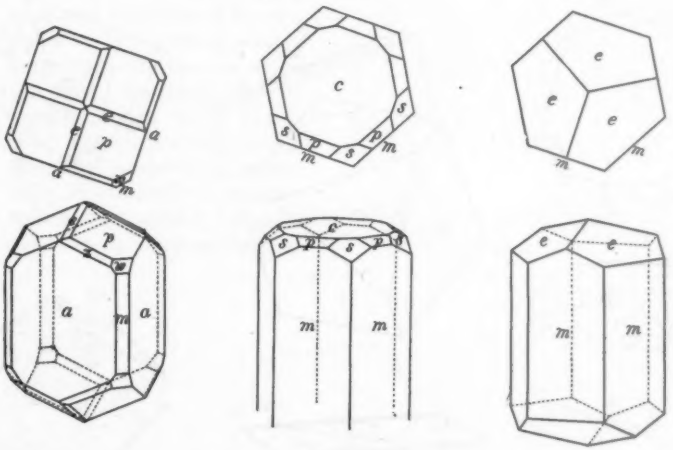
Figure 37 represents a simple combination of the tetragonal system observed on apophyllite; prism of the second order *a*, base *c*, and pyramid of the first order *p* (111). The clinographic projection alone gives a very satisfactory idea of the general proportion of the crystal, but the imagination must be drawn on to grasp the idea that the pyramid is tetragonal, a property which is brought out by a glance at the accompanying orthographic projection.

Figure 38 is a combination belonging to the tri-pyramidal group of the tetragonal system, observed on scapolite from Templeton, Canada. The forms are two prisms *a* and *m*, terminated by pyramids of the first order *p* (111) and *w* (331), of the second order *e* (101) and of the third order *z* (311). From the standpoint of a student desiring to understand the relations of the three kinds of pyramids of this group, it is believed that the orthographic is the most helpful of the two projections, although the clinographic is needed to give an idea of the general proportions of the crystal.

* Mineralogie Russlands, vol. iii, p. 47.

In the combination observed on beryl, $c$ (0001), $m$ (10$\bar{1}$0), $p$ (10$\bar{1}$1) and $s$ (11$\bar{2}$1), figure 39, it takes considerable imagination to grasp the idea of the hexagonal shape and distribution of the pyramidal forms from the clinographic projection alone, relations which are at once brought out with distinctness by means of the accompanying orthographic projection. In the rhombohedral group of the hexagonal system clinographic projections alone are at times quite inadequate for representing the shapes of crystals. For example, given the clinographic

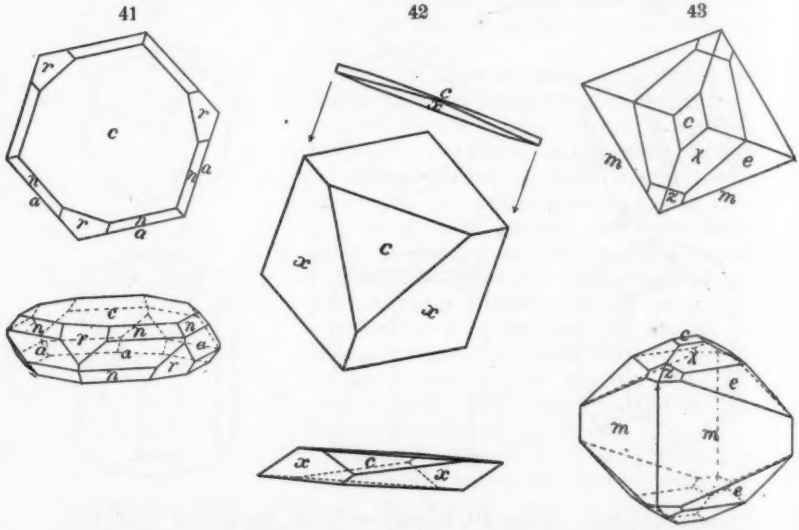
38 39 40




projection alone, figure 40, it may well be imagined that beginners have difficulty in understanding the simple type of calcite crystal represented, prism $m$, terminated by the flat negative rhombohedron $e$ (01$\bar{1}$2), but with the accompanying orthographic projection, the hexagonal nature of the prism and the distribution of the terminal faces about the vertical axis with trigonal symmetry is evident. The two projections, figure 41, supplement one another in giving an idea of the proportions and arrangement of the faces observed on a crystal of corundum from Cowee Creek, Macon Co., N. C. Figure 42 represents a crystal of hematite from Fowler, N. Y., showing the combination of the base $c$ and a very flat rhombohedron $x$ (0·1·$\bar{1}$·12). In this case the clinographic projection alone is quite inadequate, for although the figure is a correct representation in so far as the projection is concerned, it is next to impossible to gain from it a correct conception of the shape and proportions of the crystal which it is intended to represent. The

orthographic projection above, accompanied by the statement that the rhombohedron is very flat, $c \wedge x = 7° 29'$, enables one to gain an idea of the shape of the crystal, while a second orthographic projection which represents the crystal when viewed edgewise, that is so that the base is foreshortened to a line, has been introduced to indicate how very thin the crystal really is.

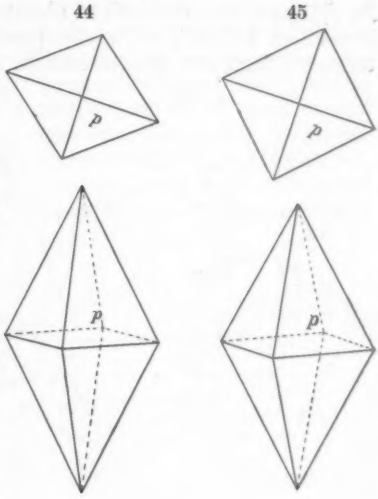
For the orthorhombic system, illustrations have already been given of the use of orthographic projections both in drawing

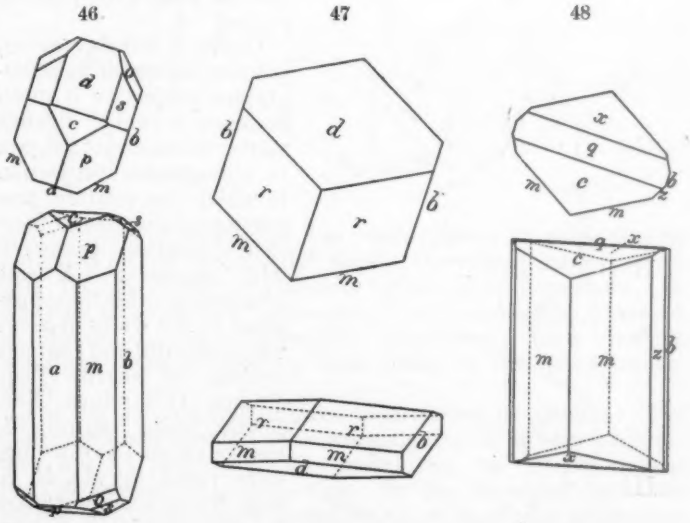



and in the understanding of the forms of barite crystals. Figure 43 is offered as an additional illustration: It represents a combination observed on brookite from Magnet Cove, Arkansas. From the clinographic projection alone it is very difficult to gain an appreciation of the proportions of the crystal; while the orthographic projection is excellent for showing the distribution of the terminal faces and zonal relations. Figures 44 and 45 represent pyramids of sulphur and octahedrite, respectively. Considering the clinographic projections alone, it takes careful inspection to discover any difference between the two figures, while the accompanying orthographic projections indicate at a glance that the pyramid is orthorhombic in the one case and tetragonal in the other.

In the monoclinic system, the clinographic projections alone, figures 46, 47 and 48, need to be supplemented by the accompanying orthographic projections in order that the real shapes

of the crystals may be fully appreciated. Taking another example; it has always seemed to the writer that the clinographic projection of epidote, figure 49, was poorly adapted for showing the form of so simple a crystal. It represents a combination lengthened in the direction of the *b* axis and terminated by two faces *n* ($\bar{1}11$), one of which, however, in the position adopted, happens to be foreshortened to a line. The accompanying orthographic projection, especially if studied in connection with a model, helps to give an understanding of

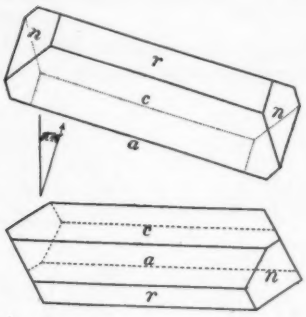


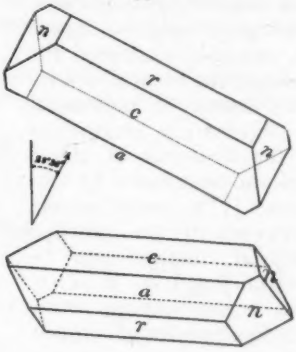

the shape. A clinographic projection better adapted for giving an idea of the development of the crystal is shown in figure 50.

In this case the revolution about the vertical axis is 28° 26′ instead of 18° 26′, as in the previous illustrations, and both terminal faces are thus shown in the lower figure. By means

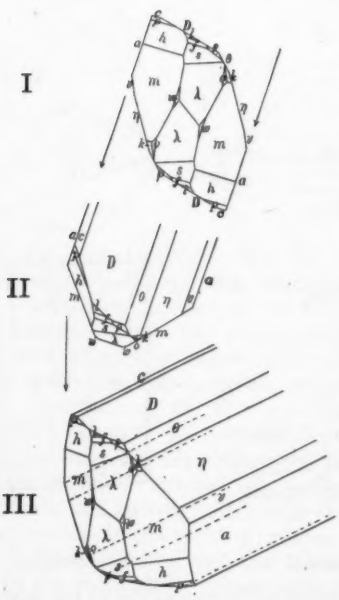
49




50




51

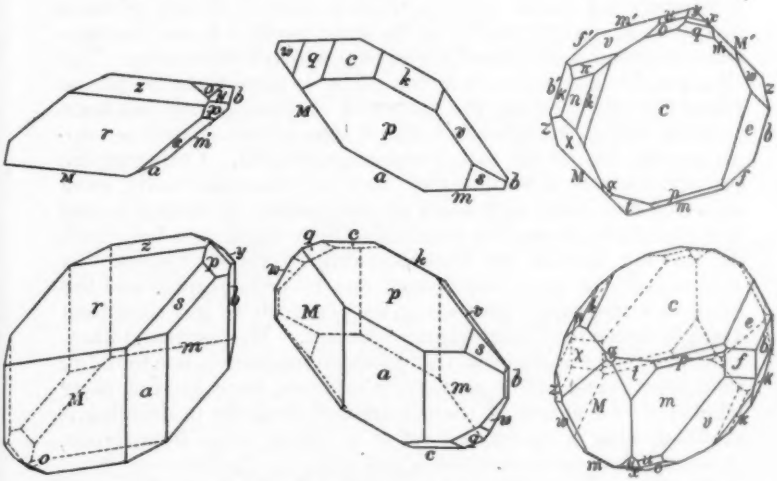



of the axial protractor, page 44, it is an easy matter to plot the axes in the position chosen.

Owing to foreshortening, without the use of an orthographic projection it often becomes a very difficult matter to construct a figure in clinographic projection in which the relative proportions of the several faces of a crystal are preserved with accuracy. A case illustrating this, encountered in the study of some very beautiful and complex crystals of azurite from Broken Hill mines, New South Wales, figure 51, may be cited. The drawings were made by Mr. R. G. Van Name when a student in the writer's laboratory. The crystals, lengthened like epidote in the direction of the *b* axis, showed only one termination, and the clinographic projection III represents the crystal turned

so that the *b* axis runs from front to back. The list of forms is not given here because, if needed, it may be found in an earlier publication.* Endeavoring to preserve the true proportions of the faces, it proved to be a difficult matter to construct the orthographic projection II, as seen in the direction of the vertical axis. An end view of the crystal, an orthographic projection as seen in the direction of the *b* axis I, was therefore first drawn, a comparatively easy task, and tilting it at an angle of 18° 26′, as shown in the figure, the

52 53 54



orthographic projection II was readily made by projecting as indicated by the arrows, and, finally, the clinographic projection III, in exactly the desired proportions was made. In studying the forms of a complex crystal, such as represented by figure 51, the orthographic projection I (end view) is doubtless more satisfactory than either of the other projections.

For the triclinic system three illustrations are offered. The clinographic projection of axinite, figure 52, is very satisfactory, but its proportions are made more real by the accompanying orthographic projection. In the examples chalcanthite and anorthite, figures 53 and 54, the clinographic projections taken alone are inadequate because of the foreshortening of several of the prominent faces, but supplemented by the accompanying orthographic projections the combinations are readily

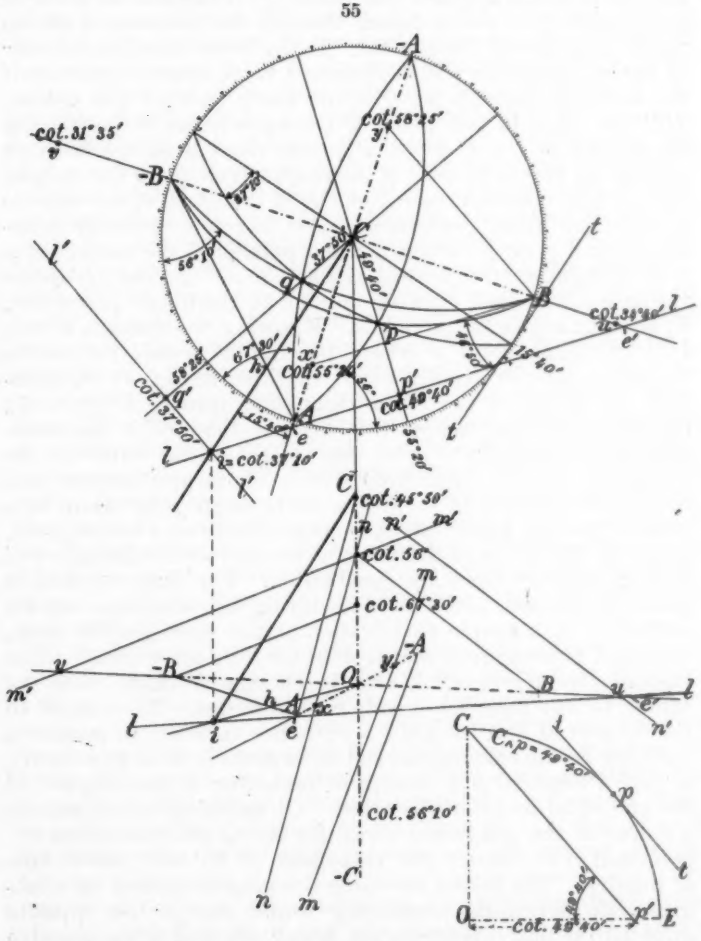
* This Journal (4), xiv, p. 278, 1902.

understood. The complicated figure of anorthite was drawn by Mr. J. C. Blake of the writer's laboratory.

*Conclusion.*—It is not the object of the present communication to make the subject of crystal drawing easy. The drawing of a complex combination requires patience, skill, and above all a knowledge of the principles of crystallography and mechanical drawing. For some persons the subject is a very easy one, while others acquire it only with difficulty, differences depending upon personal peculiarities. That correct ideas of the shapes of crystals should be obtained from figures is evident, and those who are familiar with crystallography, especially if they are not called upon to teach it, have difficulty perhaps in appreciating how hard it is for some persons to see the relations between a figure and the crystal which it represents. The clinographic projection is undoubtedly as good a one as can be found for representing the shapes of crystals, but, as has been pointed out, in many cases a figure thus drawn should be supplemented by one in orthographic projection. Orthographic projections are so simple that they may be made easily, even sketched free hand with some approximation to accuracy, and it is especially desired to emphasize their value as a help both in drawing and in the understanding of crystal figures. In the majority of cases two figures, one in orthographic and the other in clinographic projection, may be made in less time than a single figure in clinographic projection. The engraved axes, axial protractor and special triangles, having been in use for more than four years in the writer's laboratory, have proved their efficiency: by means of them increased accuracy in drawing is attained, time is saved, and, what is of no little importance, strain on the eyes is materially lessened.

*Drawing from the Stereographic Projection.*—A stereographic projection of the faces of a crystal, or, for that matter, of any geometrical figure with plane surfaces, furnishes all the data needed for constructing figures in both orthographic and clinographic projections. In the methods to be described use will be made of three lines or axes; one a vertical, corresponding to the north and south axis of a sphere, the others at right angles to one another in the plane of the equator. In the upper part of figure 55 the two diameters of the graduated circle, $A$, $-A$ and $B$, $-B$, represent the front-to-back and right-to-left axes in the plane of the equator, the vertical axis, $C$, $-C$, being foreshortened to a dot at the center. The axes have been turned as it were through an angle of 18° 26′ in order to make $A$, $-A$ and $B$, $-B$ correspond with the directions of the axes for orthographic projection of figure 1. It is supposed that in figure 55 $p$ is the pole of some crystal face: From the graduated circle it is seen that $p$ is on the meridian

55° 20′, measured from $B$, and the distance from $C$ is easily determined as 49° 40′ by means of a stereographic scale.* If




we imagine a pole corresponding to $p$ located on a spherical

*For a description of the stereographic scales and protractors mentioned in this and the succeeding paragraphs, the reader is referred to the earlier publications of the writer: "The Stereographic Projection and its Possibilities from a Graphical Standpoint," this Journal (4), xi, pp. 1–24 and 115–144, 1900; and "On the Solution of Problems in Crystallography by Means of Graphical Methods, based upon Spherical and Plane Trigonometry," Ibid., xiv, pp. 249–284, 1902.

surface, a plane surface tangent to the sphere at $p$ would be parallel to the crystal face under consideration, and, if extended, it would intersect the plane of the equator on a line at right angles to a radius drawn through the intersection of the meridian of $p$ and the equator. In the lower right-hand corner of figure 55 the arc $CE$ is supposed to represent a portion of the meridian through $p$; $C$ is the north pole of the sphere, $OE$ the trace of the plane of the equator and $tt$ the trace of the tangent at $p$: If now the tangent plane is shifted, without change of direction, until it intersects $C$ (*unity* on the vertical axis) it will intersect the radius $OE$ in the plane of the equator at $p'$. The linear projection of $p$ is therefore found by determining the point $p'$, where a plane parallel to the tangent at $p$ and intersecting the vertical axis at $C$ cuts the radius drawn through $p$, and then drawing the line of the linear projection, $ll$, at right angles to the radius. Knowing the distance $C$ to $p$ in degrees, the point $p'$ where the line $ll$ crosses the radius through $p$ may be readily found in three ways: (1) Graphically, as shown in the lower right-hand corner of figure 55; (2) From the same figure it is evident that $Op'$ is the cotangent of the angle $Cp'O$ or of the arc $C \frown p$; the value of the cotangent may be found from a table of natural tangents and cotangents and laid off on the radius through $p$ by means of a scale of decimal parts; (3) A cotangent scale may be prepared, based on the radius of the circle as *unity*, and the distance $Cp'$ laid off directly from the graduation. The latter method is probably the best, and a scale for laying off cotangents may be easily had by a simple modification of the stereographic scale, No. 3, of the engraved sheets described by the writer.* The basis of the stereographic scale is that the distance from the center to any pole, for example, $C$ to $p$, figure 55, is equal to the tangent of half the arc $C \frown p$; hence in order to prepare a scale for laying off tangents and cotangents it is only necessary to take a stereographic scale and renumber it, making 20° of the one equal to 10° of the other. On applying such a scale to a radius of the graduated circle for laying off cotangents, 90° is located at the center (the cotangent of 90°=0), and 0° falls at infinity. The reason for using a cotangent instead of a tangent scale (when the numbering would run in the opposite direction) is that cotangents are better adapted to the $\phi$ and $\rho$ angles of the two-circle goniometer. Having a second pole $q$, 37° 50′ from $C$, figure 55, its linear projection is the line $l'l'$. The two lines of the linear projection $ll$ and $l'l'$ intersect at $i$, and the direction of the edge made by the intersection of $p$ and $q$ will be parallel to the line joining $C$ and $i$.

*Loc. cit.

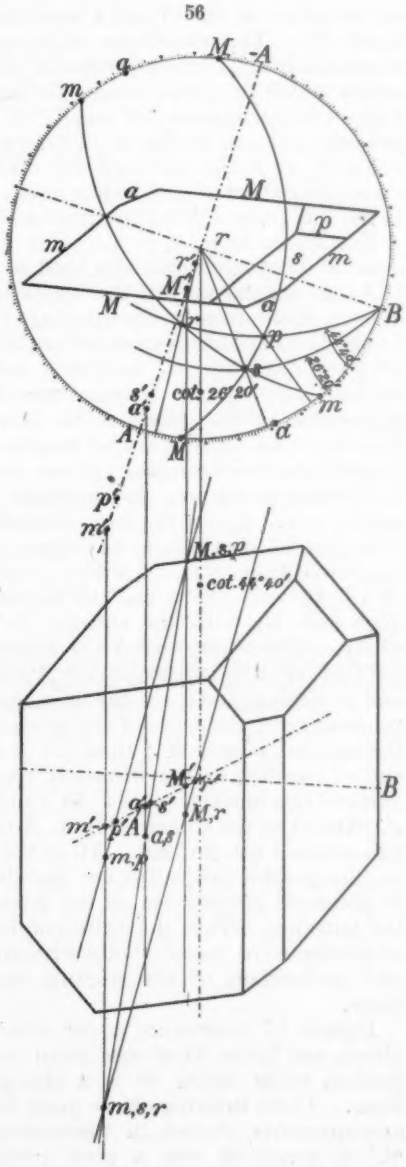
Still another way in which the direction *Ci* may be found is as follows: Among the stereographic protractors described by the writer there was one consisting only of great circles printed on celluloid (Protractor No. *IV*). Having *p* and *q* located, the protractor is centered over the projection and turned until *p* and *q* fall on the same great circle, and then the points where the great circle intersects the divided circle (15° 40′ from *B* in figure 55), are noted, although it is not necessary to draw the great circle as in the figure. It follows from this that *p* and *q* are in a zone with a vertical plane, the pole of which is located at 15° 40′ from *B*: The intersection of such a vertical plane with the plane of the equator would be parallel to the line *tt*, tangent at 15° 40′, or, simpler, it would be parallel to a line from the center *C* to a point on the graduated circle 15° 40′ from *A*, which is identical with the direction *Ci* found by means of the linear projections of *p* and *q*. The method of the great circle protractor has one decided advantage; it is not necessary to make any construction lines; the position of the protractor alone determines the desired direction. The line *Ci* in orthographic projection may be regarded as representing two things: (1) a radius drawn on the plane of the equator, and (2) the projection of the edge between *p* and *q*, passing through unity on the *C* axis and intersecting the plane of the equator at *i*: the point *i* is an important one to determine, and may be found by noticing the angle which the great circle through *p* and *q* makes with the diameter, 37° 10′ in figure 55, and locating *i* by means of the cotangent scale.

In order to find the intersection between two planes in clinographic projection, *p* and *q*, figure 55, proceed as follows: Through *C* and a point 18° 26′ to the right of *A* on the graduated circle, draw a line, and continue it for some distance below the circle, to represent the vertical axis. As shown in figure 23, page 53, the vertical axis is next made parallel with the edge of the special triangle II*a* resting on a T-square, then, at some convenient distance *O*, the lines *B*, $-B$ and *A*, $-A$ are drawn with the aid of a T-square and the special triangle II*b* to represent the right-to-left and front-to-back axes. Unit lengths on the axes are determined by projecting down from *A*, $-A$ and *B*, $-B$ of the orthographic axes above, and a distance equal to the radius of the graduated circle is laid off above and below *O*, at *C*, and $-C$, to represent unity on the vertical axis. If the special triangle referred to is not at hand, the clinographic *A*, $-A$ and *B*, $-B$ axes may be constructed readily from the details given on pages 40 and 41, in connection with figures 1 to 4. If on the orthographic axes above the linear projection of *p*, that is the line *ll*, has been drawn, its intersec-

tions with the $A$ and $B$ axis, $e$ and $e'$, are noted and points corresponding to this are projected down on the clinographic axes beneath. The line $ll$, through $e$ and $e'$ on the lower axes, is the linear projection of $p$. The point $i$, the intersection of $ll$ and $l'l'$ of the orthographic projection above, may now be transferred to the line $ll$ of the lower axes by projecting down parallel to the vertical axis: the intersection between $p$ and $q$ is parallel to the line from $C$ to $i$. If the point $i$ on the upper axes has been determined by means of the cotangent scale, without the use of the linear projection, the corresponding point $i$ on the lower axes may be found as follows: On both the upper and lower axes draw lines from $A$ to $-B$, and on the upper axes note the point $h$ where the lines $A$ to $-B$ and $Ci$ cross; on the lower axes find the corresponding point $h$ on the line $A$ to $-B$ by projecting down from $h$ above, draw a line from $O$ through $h$ and find $i$ by projecting down from $i$ above.

In following out the methods just described, two conditions may be encountered which give rise to difficulties; (1) the pole of a certain crystal face may be located within a few degrees of the center of the stereographic projection, in which case the line representing its linear projection would be so far removed from the center that it is difficult to construct it, and (2), two lines of a linear projection may happen to be so nearly parallel that their intersection falls too far from the center of the figure for convenience of drawing. Such difficulties may be overcome easily by making the linear projection either on the plane of the $A$ and $C$ axes, supposing the faces to pass through *unity* on $B$; or on the plane of the $B$ and $C$ axes, supposing that the faces intersect *unity* on $A$. To illustrate how a linear projection may be made on the plane of the $A$ and $C$ axes:—The pole $p$, figure 55, is on the meridian 55° 20′ from $B$, and a crystal face corresponding to $p$ would intersect the plane of the equator at right angles to a radius drawn to a point on the equator 55° 20′ from $B$; such a plane if shifted so as to intersect $B$ at *unity* would intersect the $A$ axis at the point marked $x$, cot. 55° 20′ (best laid off with the cotangent scale), which is projected down upon the $A$ axis beneath. The great circle stereographic protractor is next centered over the projection, and it is found that the great circle passing through $B$ and $p$ makes an angle of 45° 50′ with the equator at $B$; hence it follows that all the possible faces in the zone $Bp$, if made to intersect $A$ at unity, would intersect the vertical axis at a distance equal to the cotangent of 45° 50′ measured from the center. By means of the cotangent scale the point cot. 45° 50′ is laid off from $O$ on the vertical axis and the linear projection of $p$ is the line $nn$, drawn through $x$, previ-

ously determined, and parallel to the direction from $A$ to the point cot. 45° 50′ on the vertical axis. In the case of $q$, figure 55, being on the meridian 58° 25′ from $-B$, a little explanation is necessary: A crystal face corresponding to $q$, when shifted so as to intersect $+B$, will intersect the negative ends of the $A$ and $C$ axes; the former at the point marked $y$, cot. 58° 25′, which is projected down on the $A$ axis beneath. The great circle through $-B$ and $q$ makes an angle of 56° 10′ with the equator, and the point cot. 56° 10′ is laid off in this case on the negative end of the $C$ axis. The linear projection of $q$ is then the line $mm$, drawn through $y$ and parallel to the direction from $-A$ to the point cot. 56° 10′ on the vertical axis. The lines $nn$ and $mm$ intersect at some distance from the center of the axes, but if continued it is found that a line from $+B$ to their point of intersection is parallel to the direction $Ci$. If it is desired to make the linear projection

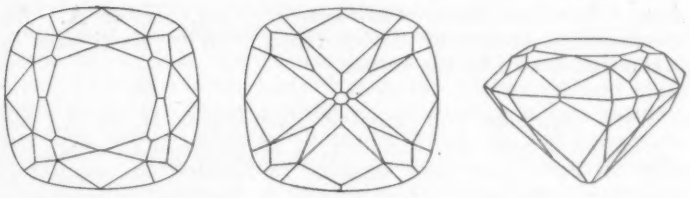


on the plane of the $B$ and $C$ axes, the data are as indicated in figure 55: The meridians of $p$ and $q$, 34° 40′ and 31° 35′, measured from $A$ (their cotangents plotted at $u$ and $v$), and the angles which the great circles through $A$ and $p$ and $A$ and $q$ make with the equator, 56° and 67° 30′, respectively. The linear projection of $p$ is the line $n'n'$, drawn through $u$ parallel to the line from $B$ to the point cot. 56° on the vertical axis; and the linear projection of $q$ is the line $m'm'$, drawn through $v$, parallel to the line from $-B$ to the point cot. 67° 30′ on the vertical axis. A line drawn from $A$ to the point of intersection of $n'n'$ and $m'm'$ is the desired direction, and is parallel to the line $Ci$.

As an illustration of the application of the methods just described, the details of a drawing of a crystal of axinite may be cited. The forms present are shown in the stereographic projection, figure 56: $m$ (110), $a$ (100), $M$ ($1\bar{1}0$), $p$ (111), $r$ ($1\bar{1}1$) and $s$ (201). It was found that on making the linear projection on the plane of the $A$ and $B$ axes, several of the lines were so nearly parallel that it was difficult to determine some of the intersections. It was decided, therefore, to make the linear projection on the plane of the $A$ and $C$ axes as shown in the figure, the data needed being derived from the stereographic projection, as follows: Meridians of the poles, measured from $B$: $m$ 32° 47′; $p$ 35° 50′: $a$ 48° 21′; $s$ 51°; $M$ 77° 16′ and $r$ 85°; also the angles made by the great circles $Bpr$ and $Bs$ with the equator, 44° 40′ and 26° 20′, respectively. The cotangents of the meridians of the several poles are laid off on the orthographic $A$ axis at $m'$, $p'$, $a'$, $s'$, $M'$ and $r'$, and projected down on the clinographic $A$ axis. The linear projections of the faces of the prismatic zone are vertical lines through $m'$, $a'$ and $M'$; those of $p$ and $r$ are lines through $p'$ and $r'$, parallel to the direction from $A$ to the point on the vertical axis marked cot. 44° 40′; and that of $s$ the line through $s'$, parallel to the direction from $A$ to the point on the vertical axis marked cot. 26° 20′. All of the intersections of the figure in clinographic projection are parallel to lines drawn from $B$ to points of intersection on the linear projection, indicated by the lettering. Thus the orthographic and clinographic figures of axinite were made wholly without reference to the lengths and inclinations of the triclinic axes and the symbols of the faces.

Figure 57 represents a cut stone (brilliant) as seen from above, and figure 58 as seen from below in orthographic projection, while figure 59 is a clinographic projection of the same. These drawings were made from two-circle goniometer measurements plotted in the stereographic projection. The object measured was a glass model of the Regent or Pitt diamond.

57 58 59



It is scarcely necessary to state that drawings may be made from gnomonic as well as from stereographic projections, with but slight modifications of the methods just described.

It is the writer's belief that the average student will find it easier to draw crystals from axes and the symbols of crystal faces, as set forth in the earlier part of this paper, than from the stereographic projection. Cases may arise, however, in which the latter methods may be found useful, as, for example, in finding the intersections between faces of twin crystals, or in representing some odd shapes which can not be referred to the axes of the crystal systems.

Mineralogical Laboratory of the
Sheffield Scientific School of Yale University,
New Haven, Conn., November, 1904.

NOTE.—If any desire to make use of the Engraved Axes, page 43, the Protractor for plotting Crystallographic Axes, page 44, or the Special Triangles, page 53, the writer will be glad to answer any communications and see that the necessary articles are supplied from his laboratory.

ART. VI.—*Anemiopsis Californica* (Nutt.) H. et A. An anatomical study; by THEO. HOLM. (With six figures in the text drawn by the author.)

WITH Bentham and Hooker *Anemiopsis* H. et A. and *Gyrotheca* Dcsne. are included in *Houttuynia* Thunbg., but they all have been kept separate by Eichler* on account of their floral structures. *Houttuynia* is described as possessing only three stamens opposite the three carpels, while in *Anemiopsis* and *Gyrotheca* the flower has six stamens and three carpels in the former, but four in the latter; the ovary is, moreover, perfectly inferior in *Gyrotheca*. The arrangement of the stamens in *Anemiopsis* is somewhat peculiar, as already described by Payer, there being two in front and two behind the ovary, with one on each side of this; this position of the stamens was, also, observed by the writer in the several inflorescences examined. Furthermore, DeCandolle† has treated our genus as distinct from the others.

*Anemiopsis Californica* does not seem to be very well known anatomically, and since the writer has lately received some fresh and carefully collected specimens from California through our friend Mr. Thos. H. Kearney, we have examined the plant and offer now the following notes as a small contribution to the knowledge of this peculiar genus.

The thick rhizome is horizontal with several strong and quite fleshy roots; its ramification is monopodial, the apical bud being purely vegetative, while the stolons and flower-bearing stems are all lateral, proceeding from the axils of the leaves, which form an open rosette. While, as already pointed out by Eichler (l. c.), the flowers are destitute of prophylla, such occur at the very base of both the stolons and flower-bearing stems, thus representing clado-prophylla.‡ These leaves are two in number and situated to the right and left of the stems; they are membranaceous, scale-like and prominently carinate, but simply one-nerved. The flower-bearing stems are often branched, there being one terminal and two or three lateral inflorescences preceded by one or two green leaves. The stolons show the same structure, but with vegetative shoots instead of inflorescences.

Considered from an anatomical viewpoint the *Piperaceæ*§ have always attracted a good deal of attention, and they figure

* Blüthendiagramme, vol. ii, 1878, p. 6.

† Prodromus, vol. xvi, 1869, p. 237.

‡ Compare Casimir DeCandolle: Mémoire sur la famille des Pipéracées. (Mém. Soc. phys. Genève, vol. xviii, 1865, p. 234.)

§ The anatomy of the order has been described in Dr. H. Solereder's work: Systematische Anatomie der Dicotyledonen. Stuttgart, 1899, p. 775.

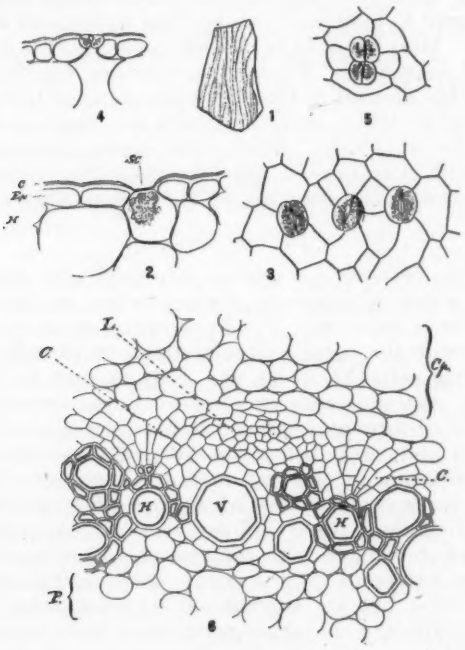
prominently in works upon general anatomy. Not less than four types of stem-structure are described by Dr. Solereder (l. c.), and characteristic of the tribe *Saurureæ*, to which our genus belongs, is one normal ring of collateral mestome-bundles. In regard to the leaf-structure the stomata are said to be confined to the lower surface; in *Anemiopsis*, however, we observed these to be present also on the upper, and even more numerous. Most peculiar is the development of a hypoderm, so very prominent in *Peperomia*, besides the hydathodes. Secreting cells abound in the leaves and stems of both *Pipereæ* and *Saurureæ*, while secreting ducts are only known from some species of *Piper*. Very little seems, however, to be known about *Anemiopsis*, thus we take the opportunity to describe herewith the structure of the various organs in detail.

### *The leaf-blade.*

The cuticle of both surfaces is quite thick and prominently wrinkled, which is especially distinct when we examine the epidermis from above (fig. 1). Epidermis consists of relatively small cells with the outer wall moderately thickened except in the secreting cells (*SC* in fig. 2). For, as may be seen from this figure, secreting cells occur, also, in the epidermis; they are thin-walled throughout, much larger than the ordinary epidermis-cells and sunk below the level of these, thus forming round depressions in the leaf-surface. Long hairs abound on the lower surface and consist of from eight to twelve cells in one row with the cuticle thin and smooth. As stated above, we observed stomata on both surfaces, and they appeared even to be most numerous on the upper; they have no specialized subsidiary cells, but are surrounded by a somewhat indefinite number of ordinary epidermis cells, from four to six, as may be seen from our fig. 3; viewed in transverse sections, the stomata are level with epidermis (fig. 4). A hypoderm of one layer of cells (*H* in fig. 2) is developed on both faces of the blade, but of different structure; the cells are very large and cone-shaped on the upper face with the point towards the palisade-tissue; on the lower face the hypodermal cells are relatively smaller and of a roundish outline (fig. 2).

The leaf is dorsiventral and possesses a distinct palisade-tissue of several layers on the upper face, interrupted here and there by secreting cells; the palisades are rich in chlorophyll and surround the conical, hypodermal cells, but without reaching the epidermis. A pneumatic tissue of irregular, oblong cells, with wide intercellular spaces, occupies the dorsal part of the blade. The mestome-bundles, except the mediane, are small and completely imbedded in the mesophyll; they are surrounded by a colorless parenchyma-sheath. The midrib is

quite broad and projects on the lower surface, where it borders on a large mass of thin-walled, colorless parenchyma. It is composed of seven separate mestome-bundles, each with a parenchyma-sheath and having a support of several layers of stereomatic tissue, especially on the leptome-side.




*Anemiopsis Californica.*

FIG. 1.—A cell of epidermis from the leaf, showing the wrinkled cuticle, seen from above.

FIG. 2.—Transverse section of the leaf; $C$ = cuticle; $Ep$ = epidermis; $SC$ = secreting cell of epidermis; $H$ = hypoderm.

FIG. 3.—Epidermis with stomata of the leaf, seen from above.

FIG. 4.—Transverse section of leaf, showing a stoma.

FIG. 5.—Epidermis with twin-stomata, seen from above.

FIG. 6.—Transverse section of a part of the central-cylinder of the root; $L$ = leptome, outside a secondary vessel $V$; $C$ = cambial layers; $H$ = the primordial rays of hadrome; $P$ = pith; $Cp$ = secondary cortical parenchyma.

### *The petiole.*

The cuticle shows the same structure as described above; the epidermis possesses stomata, but no hairs, and is rather small-celled. A hypoderm is, also, developed here, but it is uniform and consists only of one layer of roundish cells. The

cortical parenchyma, at least the peripheral strata, contains chlorophyll, and is very open from the great width of the intercellular spaces; secreting cells occur, also, here, but are not very frequent. Separating the cortex from a central group of parenchymatic tissue, a pith, is a circle of twelve collateral mestome-bundles, each with a thin-walled parenchyma-sheath, and surrounded besides by strata of stereomatic tissue. The stereome, however, is confined to the periphery of the mestome-bundles themselves, and does not connect these as a continuous ring of mechanical tissue as is the case with the stem. Characteristic of the mestome-bundles in the petiole is their elliptical outline in cross-section with the leptome, forming a narrow, linear group in contrast to the broad group of hadrome with numerous, narrow vessels.

*The prophylla.*

As already mentioned, the stolons and flower-bearing stems are axillary; they bear at their base two scale-like, membranaceous fore-leaves, the structure of which is as follows: The cuticle is very distinctly wrinkled on the outer, the dorsal face, but smooth on the inner, the ventral. Epidermis is thin-walled and consists of relatively small cells throughout with neither trichomes or stomata; the outermost portion of the margins is merely composed of epidermis in two layers corresponding to the dorsal and the ventral. The mesophyll is very poorly represented except in the sharp keel; it is quite open and does not contain chlorophyll, neither is it differentiated as a palisade or pneumatic tissue, but constitutes a homogeneous tissue of roundish, thin-walled cells. There is only one mestome-bundle, which is located in the keel; it has a support of two or three layers of slightly thickened stereome and contains mostly leptome.

*The involucre.*

The involucral leaves at the base of the inflorescence are very conspicuous, being large and white; they are prominently papillose on the ventral face, each epidermal cell being extended into an obtuse papilla, while the dorsal face is perfectly smooth. Stomata and secreting cells occur in the dorsal epidermis. A hypoderm of large, roundish cells is developed underneath the epidermis on both faces of the involucre. The mesophyll is almost destitute of chlorophyll; it is homogeneous and traversed by wide, intercellular spaces, besides by several very small mestome-bundles.

*The floral bracts.*

The cuticle and the epidermis exhibit exactly the same structure as observed in the involucre, while the hypoderm is absent

from the ventral face and but slightly differentiated on that of the dorsal. The homogeneous, somewhat open mesophyll contains a little chlorophyll, and about seven very small mestome-bundles are located in the middle of this tissue.

*The stem.*

The long stolons above ground and the flower-bearing stems show the same structure. They are nearly cylindric, slightly hairy, but perfectly smooth. We notice, also, here a wrinkled cuticle, covering an epidermis of relatively small cells of which the outer wall is distinctly thickened; none of the epidermal cells were transformed into secreting cells. Underneath the epidermis is a hypoderm of only one layer of very large, roundish cells, much larger than those of the adjoining cortex. This tissue, the cortex, consists of about fifteen strata, of which only the peripheral contain chlorophyll; the innermost layer is differentiated as a thin-walled endodermis, surrounding a continuous ring of about fifteen layers of very thick-walled stereome. Directly bordering on the stereome is a circle of twenty-four collateral mestome-bundles separated from each other by broad medullary rays; they are oval in cross-sections and contain both leptome and hadrome, the latter consisting of a few, but wide vessels. But there is no parenchyma-sheath and no mechanical support on the sides of these mestome-bundles or around the hadrome. The central pith is very thin-walled and open. Secreting cells abound in the cortex and in the pith.

*The rhizome.*

The horizontal rhizome is cylindric, glabrous and smooth; towards the apex it is densely covered with sheathing, green leaves, and is not exposed to the light. Its free portion, behind the rosette of leaves, becomes soon deprived of both the epidermis and hypoderm, but protected by many layers of cork. The cortical parenchyma consists of about fifteen layers with wide intercellular spaces; the cells are filled with starch or contain a secretion of a reddish brown color. The very numerous mestome-bundles are narrow oblong in transverse sections, and are nearly all arranged in a circle separated from each other by rays of the very broad, central pith, which contains starch. The leptome occupies only a small portion of the mestome-bundles, and between this and the very prominently developed hadrome are several strata of cambium.

*The root.*

All the roots were so far advanced that they showed only a secondary stage of growth. By the increase in thickness the

tissues from epidermis to pericambium had been thrown off and replaced by some, five to six, layers of cork and a very large parenchyma of secondary cortex, filled with starch or sometimes interspersed with secreting cells. Towards the central cylinder the cells of the cortex decrease in size and the innermost layer shows somewhat the structure of a secondary endodermis by its darker color and its power to resist the effect of concentrated sulphuric acid. The central cylinder, however, shows a part of its original structure, viz: a circle of nine short hadromatic rays, each consisting of a few, narrow vessels (*H* in figure 6). These rays alternate with nine collateral mestome-bundles in which the vessels are quite wide (*V* in fig. 6), and mostly more thin-walled than the primordial. Several layers of cambial tissue (*C* in fig. 6) are developed outside the old vessels and inside the groups of leptome, where the secondary hadrome has become developed. A broad and compact pith occupies the inner part of the central cylinder, thus the structure of the root corresponds very well with that of the stem, if it were not for the presence of the primordial rays of hadrome between the collateral mestome-bundles.

*Summary.*

Being an inhabitant of moist, saline localities our plant may, perhaps, be regarded as a Halophyte. The structural peculiarities of this category of plants has been studied to some extent, but as yet too little has been ascertained to enable us to draw the line between Halophytes and Xerophytes or even the Hydrophytes. Moreover, there are certain orders of plants in which the structural peculiarities appear as characteristic of the order and to some extent inherited, rather than being an expression of a certain mode of adaptation, such as the epharmonic characters.

Now in regard to *Anemiopsis Californica*, it certainly appears as if the structure may be defined more properly as simply "piperaceous" than either halophilous or xerophilous. The most conspicuous characters—the prominently developed hypoderm and the abundance of secreting cells throughout the various tissues—are in conformity with the general structure of the order rather than with the Halophytes, for instance, and these characters are very important. Then when we compare the tables of "leaf-anatomy of salt-marsh species" in Mr. Kearney's interesting paper on this subject,* we notice several points by which our plant differs from his salt-marsh species.

* The plant covering of Ocracoke Island. Contrib. U. S. Natl. Herb., vol. v, Washington, 1900, p. 310.

Most of the species examined by this author possess isolateral leaves; several of these have hypodermal collenchyma or the mestome-bundles are supported by real stereome. On the other hand, Mr. Kearney observed a wrinkled cuticle and a like distribution of stomata on both leaf-surfaces, both of which characters, as we remember, are also to be observed in *Anemiopsis*. A similar result is reached when we compare the species examined by Professor Warming,* none of which possess such striking peculiarities as those characteristic of the *Piperaceæ*, nor do the features of his Halophytes in general agree with those of our plant; only a few points and of no particular interest or of seemingly great importance may be found common to both. As stated by Professor Warming, the lack of stereome seems to be characteristic of the Halophytes, so far as concerns their leaves, and only these have been examined. In this respect *Anemiopsis* would show some likeness to the Halophytes, since the leaves contain very little stereome and only near the midrib. But if we compare the other parts of the plant, the stem and the petiole for instance, we then observe this tissue to have reached a very high development, especially in the flower-bearing stems and the stolons.

It would, thus, appear as if *Anemiopsis* so far as concerns the structure, gives a better illustration of one of the several types of the *Piperaceæ* than of any specialized type modified in accordance with the environment, halophilous for instance.

Brookland, D. C., October, 1904.

* Halofyt-Studier, Kgl. Danske vid. Selsk. Skr., 6th series, vol. viii, Kjöbenhavn, 1897, p. 175.

# SCIENTIFIC INTELLIGENCE.

## I. Chemistry and Physics.

1. *The Production of Pure Sodium Hydroxide for Laboratory Uses.*—On account of the danger in dissolving any considerable amount of metallic sodium directly in water, because of the very violent explosions that are likely to take place from an unexplained cause, even with bright metallic sodium, F. W. Küster has devised a method for effecting this solution slowly by the help of moist air, and has thus obtained a very satisfactory and cheap caustic alkali solution. He places a bell-jar in a large, flat dish in which there is sufficient water to make a water-seal, and under the ball-jar he places a platinum, silver, or nickel dish, crucible, or wide-necked flask, as a receptacle for the caustic solution. Above the receptacle is placed upon a tripod a piece of nickel wire gauze, bent into a conical shape with its apex downward, and in the cone pieces of sodium are placed after the outer crust has been cut off. The sodium begins at once to deliquesce while bubbles of hydrogen escape through the water-seal, and the resulting sodium hydroxide solution drops as a very concentrated, oily liquid from the point of the cone into the dish below. The operation goes on until all the sodium has been used up, and at last certain impurities of the sodium remain upon the wire-gauze, so that this process gives a purer product than direct solution. The solution thus obtained is of about 40 per cent strength, and it may be kept absolutely free from carbonate.—*Zeitschr. anorgan. Chem.*, xli, 474. H. L. W.

2. *The Production of Magnetic Alloys from Non-Magnetic Metals.*—R. A. Hadfield, who has produced the well-known non-magnetic alloy of iron and manganese known as "manganese steel," calls attention to the interesting fact that a magnetic alloy can be produced from the non-magnetic metals, copper, aluminium, and manganese. A sample of this alloy, which appears to have been prepared by Dr. F. Heusler, contains 60 per cent copper, 25 to 27 per cent manganese, 12 per cent aluminium, 6 to 7 per cent silicon, 0·5 to 1 per cent carbon and probably 0·5 per cent iron; but samples containing absolutely no iron had exactly the same magnetic properties. It has been found that no alloy of copper and aluminium is magnetic, hence it appears that the magnetic properties of the alloy are due to manganese, which, curiously enough, produces the non-magnetic alloy with iron. It is to be observed, however, that the alloy under consideration requires the presence of a certain amount of aluminium in order that it may be magnetic, and that with fairly constant contents of manganese amounting to 25 to 28 per cent, the maximum "magnetizability" is reached when 14 per cent of aluminium is present.—*Chem. News*, xc, 180. H. L. W.

3. *Ozobenzol.*—A product of the action of ozone upon benzol

was named and described by Renard a number of years ago, and the formula $C_6H_6O_6$ was then ascribed to it. HARRIES and WEISS have recently re-investigated this substance and find that its formula is $C_6H_6O_9$; that is, three molecules of ozone attach themselves to benzol, presumably at the points of double linking, according to Kekulé's theory. The compound forms a gelatinous mass when ozonized oxygen is allowed to act at 5–10° upon benzol. It is fearfully explosive, resembling iodide of nitrogen in this respect. When ice-cold water is placed upon the amorphous substance it assumes a crystalline modification which is also exceedingly explosive. It appears that the formation of this compound is a support to Kekulé's benzol theory.—*Berichte*, xxxvii, 3431. H. L. W.

4. *Concerning Emanium.*—Some time ago GIESEL announced that he had found a new radio-active substance related to lanthanum, which was characterized by its remarkable action upon the blende screen. He has recently been able to compare the action of this "emanium" with Debierne's actinium, which is related to thorium, and finds that the two substances show no difference with the screen. He is still inclined to believe, however, that there may be a difference in the substances, on account of an apparent slight difference in the rates of decay of their induced activity, and also on account of the fact that three lines which the phosphorescence of his substance shows in the spectroscope have not been found with actinium.—*Berichte*, xxxvii, 2963.

H. L. W.

5. *The School Chemistry;* by ELROY AVERY. 12mo., pp. 423. American Book Company, 1904.—This new text-book for high schools and academies is noticeable for being more extensive in its scope, both in the descriptive and theoretical parts of the subject, than is usual with books of this class. The experiments introduced are numerous, more than 300 being given, and they appear to be very well chosen for the purposes of instruction. A particularly good feature of the book is the number and variety of arithmetical problems, and other thought-inducing questions, that are presented. Although the book is well up-to-date in its facts, since such recent topics as radio-activity are discussed, the treatment of chemical theories may be considered as somewhat old-fashioned. For instance, there appears to be no mention of ionization, although many electrolytic experiments are given, and although the "changing places" of atoms or groups in reactions is frequently alluded to. A few inaccurate or misleading statements have been noticed in the book, but these do not appear to be unduly numerous. It is to be hoped, since hydrogen was solidified several years ago, that the characterization of lithium as the lightest solid known will soon disappear from our text-books, because it is about seven times heavier than solid hydrogen. H. L. W.

6. *Application of Some General Organic Reactions;* by Dr. LASSAR-COHN. Authorized Translation, by J. BISHOP TINGLE.

12mo., pp. 101. New York, 1994 (John Wiley & Sons).—The topics discussed in this book are "Fixation of Hydrogen Atoms," "Modification of Reactions," "Improvement in Conditions of Reactions," and "Influence of Atoms and Atomic Complexes." These subjects are of importance, and have not received sufficient attention in other works. The simple and entertaining manner in which the book is written should make it of interest not only to the experienced chemist, but also to the beginner in organic research. T. B. J.

7. *Influence of Glass Walls of Geissler Tubes on Stratified Discharges in Hydrogen.*—E. GEHRCKE, of the Reichsanstalt, finds that the glass walls exert a marked influence on the length of such stratifications. Not only the curves drawn from measurements but the appearance of the stratifications in suitable tubes show this influence. To make the effect evident to the eye one side of the inner wall of a Geissler tube was covered with silver; this had the effect of changing the length of the stratifications. The inner walls were also covered in another case with a layer of phosphoric pentoxide, with the same result. The author refers the stratifications observed in open space in flames to an effect of secondary cathodes. The stratifications in Geissler tubes appear to be a chain of cathodes with dark spaces and light spaces; the potentials of which seem to form an arithmetical series, and each stratification hands on to the next as much negative electricity as it received from the previous one. Foundation for a suitable mathematical theory is discussed.—*Ann. der Phys.*, No. 13, 1904, pp. 509–530. J. T.

8. *Phosphorescence.*—P. LENARD and V. KLATT continue their researches on this subject. Among their interesting conclusions is the following: Stokes's law that the waves of excited light are always longer than those of the exciting light has not been sustained by analysis of the sixty-four fluorescent bands examined. If the range of the exciting and the produced light are compared, it is seen that the exciting light and the fluorescent bands often approach each other very nearly; sometimes coincide, but never overleap each other. Study was made of momentary and more or less permanent fluorescence and of their dependence on exciting conditions.—*Ann. der Phys.*, No. 13, 1904, pp. 425–484. J. T.

9. *Color Changes in Gold Preparations.*—The theory of electrical resonance has been applied by various observers to account for the phenomena presented by colloidal preparations of gold in reference to color. F. KIRCHNER and R. ZSIGMONDY have had in view especially Planck's work in this direction. Their results support in general Planck's theory. There were, however, noticeable lacunæ between the theory and the observations.—*Ann. der Phys.*, No. 13, 1904. J. T.

10. *Spectra of Hydrogen, Helium, Air, Nitrogen, and Oxygen in the Ultra Violet.*—With the aid of a quartz spectroscope, J. SCHNIEDERJOST has made a study of these gases. Comparison lines of platinum were employed. Two new lines of helium at

wave-lengths 2653·1 and 2644·9 were discovered which belonged to the first main series. Deslandres' nitrogen group which lies between wave-lengths 3009·6 and 2205·3 was investigated, and Deslandres' results confirmed. Seventy new lines of the line-spectrum of nitrogen were also measured. A number of new lines of oxygen were also discovered.—*Diss. Halle*, 1904. *Beiblätter, Ann. der Phys.*, No. 22, 1904. J. T.

11. *Pressure of Light.*—In a sealed communication to the R. Accad. dei Lincei in 1882, opened at the meeting of February 1, 1903, A. Bartoli relates that certain experiments conducted in the year 1876 appeared to show that the pressure of light apparently confirmed by late experimenters does not really exist, and that there arises a certain resistance which a reflecting body encounters in a region of radiation, and which in the movement of a reflecting body would be shown in the body without a normal component in consonance with the second law of thermodynamics. He suspects further that the work for overcoming this resistance is changed into electric currents in the reflecting metal. These currents should be of measurable size. This suspicion was apparently confirmed by experiment. He mounted a strong circular disc upon the axis of a solid lathe. This disc had a circular highly-reflecting band which was insulated by dry wood soaked in oil. The band was cut and the two ends were connected to two rubbing insulated contacts and to a sensitive galvanometer. The velocity of revolution of a point on this band was 240–410 meters per second. When sunlight fell on the silvered band the thermo-electric effect was only $2{\cdot}3^{mm}$ deflection if the disc was at rest. When the disc rotated in the dark there was no reflection. As soon as sunlight fell on the rotating disc the galvanometer gave a deflection of $42^{mm}$, and this deflection persisted while the sunlight remained. It disappeared when the sunlight was removed. When the revolution was reversed the deflection was reversed to $-32^{mm}$. A half speed gave a deflection of $20^{mm}$. These experiments were made in August and September, 1880, in the Technical Institute of Florence, and were so far as is known never resumed.—*Beiblätter, Ann. der Phys.*, No. 22, 1904. J. T.

12. *Notes on X-Light;* by William Rollins. Pp. 400, plates 150, Boston, 1904.—This beautifully printed volume contains the arduous researches of a professional man who has devoted his evenings to what is perhaps the most baffling and trying of all physical research, experimentation on gases at low vacuo—trying both to physical endurance and to the spirit; for just as nature seems to be inclined to open her mysterious chambers, the glass apparatus and the mechanical apparatus employed in producing such vacuo breaks, and the course of experimentation has to be begun anew. The expenditure of time and money, in giving freely to physicians and surgeons the best means of producing and employing the X-rays, shown by this book is remarkable, especially when one reviews the history of the use of these rays and sees the endless effort to secure all

improvements in tubes or processes of regulation by patents. Following the method adopted by Faraday, the author relates both positive and negative results of his experiments. In the subject of rarified gases, especially at low pressures, this method in the present uncertainty of our knowledge is most useful; for, like the story of the Alpine climber who relates his attempts to scale some most difficult aiguille, it stimulates the imagination and leads to a consideration of all possible paths in the hope of finding, even through failure, a way to the summit; and in ultimate success, the first path-breaker should not be forgotten. In reading the list of contents of this volume one is surprised at the richness of suggestion. Every form of X-ray tube, of regulators and of exciters for such tubes, receives thought, and it is recognized by those who have followed Dr. Rollins' work that the present forms of the most enduring and most efficient tubes are the result of his work. Makers of such tubes have eagerly taken up his suggestions and by (we will charitably say) unconscious cerebration have taken credit to themselves. This is true also of the open construction of Ruhmkorf coils which the author fully describes in his book, and the employment of a hinged Faraday ring in the primary of such coils. This is a most efficient construction of a transformer both for X-ray work, for spectrum analysis, and for wireless telegraphy. No one in America appears to have had the experience of Dr. Rollins in exhausting X-ray tubes to their point of greatest efficiency. He points out many phenomena of absorption and occlusion of gases by the various terminals he employed, and by the glass walls of the enclosure which are now being studied quantitatively by various observers. This occlusion or absorption can under certain conditions reduce the pressure in an X-ray tube from one-thousandth of a millimeter to one two-thousandth. The mechanical skill shown in the plates of appliances for the employment of X-rays in surgery, which are collected at the end of the volume, would suffice alone to make this a notable work and a monument of altruism. J. T.

## II. Geology and Mineralogy.

1. *Indiana Geological Survey.* — W. S. Blatchley, State Geologist. 28th Annual Report, 1903, 553 pp., with plates, maps and figures.—In addition to the statistical reports of the mine inspector, the gas supervisor, etc., the Indiana Survey Report for 1903 contains articles by T. C. Hopkins and A. F. Foerste on the Topography and Geological Formations of the state accompanying the new Geological Map; and a paper on the Stratigraphy and Paleontology of the Niagara, by E. M. Kindle. There is also a valuable table of contents of all of the geological literature published by the state of Indiana. The report of the state gas supervisor brings clearly to mind the great waste that has been caused by the careless treatment of the natural gas supply. The people of the state have finally been convinced that the gas sup-

ply is not inexhaustible. It is fast declining and the end is not far off. Most of the present drilling is done in territory abandoned years ago, and the average well now drilled would have been considered a failure ten years ago. The price of gas has increased fivefold in ten years and at the present time more pipeline is being taken out of the ground than put in it. Two large gas companies have entirely abandoned the city of Indianapolis.

2. *Geological Map of Indiana.* — A new geological map of Indiana has been published under the direction of W. S. Blatchley, state geologist, on a scale of four miles to the inch. This map is a compilation of all the stratigraphic work done in the state from 1895 to 1903 inclusive, while the actual work of preparation is by T. C. Hopkins. Accompanying the map is a short description (77 pp.) of the topography of Indiana and of the chief geologic formations of the state. No attempt has been made to represent the rock structure underneath the heavy glacial deposits covering the northern part of the state for a distance of about forty miles.

3. *Geological Survey of New Jersey;* Henry B. Kümmel, State Geologist. Vol. VI, 533 pp., 56 pls., 41 figs.—The latest volume of the New Jersey survey deals with the Clays and Clay Industry of New Jersey, and is written by Heinrich Ries and H. B. Kümmel, assisted by G. N. Knapp. The report deals with the occurrence, chemical and physical properties of clays, the stratigraphy of the clays and the method of their manufacture. A very complete set of fire brick tests has been made, particularly in reference to its refractoriness. A striking commentary upon the efficiency of the New Jersey survey is the fact that the clay maps of 1878 are found to be accurate in spite of the great development of the industry since that time.

4. *Recent Seismological Investigations in Japan;* by Baron Dairoku Kikuchi, Emeritus Professor of Mathematics Tōkyō Imperial University, Member and former President of the Imperial Earthquake Investigation Committee. Pp. ix + 120. 54 illustrations. Tokyo, 1904.—This volume, stamped "for private circulation only," was distributed at the Japanese exhibit of the recent exposition in St. Louis. As stated in the introduction, Japan is preëminently the land of earthquakes, and following the great Mino-Owari earthquake of October, 1891, in which over 7000 people were killed, the Imperial Earthquake Commission was established with a twofold object. First, to investigate whether there are any means of predicting earthquakes; and, secondly, to determine how to reduce the disastrous effects to a minimum. With characteristic Japanese insight and thoroughness the commission decided that the best way to attain its objects was first, possibly for many years, to study earthquakes in every relation, even such as might appear to have little or no bearing upon the immediate objects. The results of these investigations are given in sixteen publications in foreign languages, a list of which is given in the back of this volume. Among the more

noticeable features of the present volume are charts giving the time, distribution and periodicities of Japanese earthquakes for over a thousand years, and studies in the variations in magnetism, latitude and other physical changes as possibly having relations with the occurrence of severe earthquakes. For more than a decade astronomers have been familiar with the fact, rendered evident by long continued and refined astronomic observations in several parts of the world, that the earth's axis of rotation is not absolutely fixed, but that, on the contrary, the poles wander through a period of years in a complex path within a circle of a few hundred feet radius. Among other results the commission has found that the seismic activity of Japan presents a period of six and one-half years, and in the past nine years all the destructive earthquakes occurred exactly or very nearly when the latitude was at a maximum or minimum. J. B.

5. *Earthquakes, in the Light of the New Seismology;* by CLARENCE EDWARD DUTTON, Major U. S. A. Pp. xxiii+314, with 63 illustrations. New York (G. P. Putnam's Sons), London (John Murray), 1904.—This is volume 14 of "The Science Series," and while clear and readable throughout, nevertheless enters into all the chief problems related to earthquakes and is a volume which should be read by every teacher of physical geology. Previous to 1870 the studies published were with few exceptions little more than narratives of disasters. Since that time, largely through the labors of Ewing and Milne, who have more recently been joined by many other investigators, the subject has grown into an exact science which not only reveals the location of regions of unstability whether at the antipodes or even under the ocean, but which is throwing light upon such problems as the density and solidity of the earth's interior.

After discussing the nature and causes of earthquakes, the author devotes 48 pages to the subject of earthquake instruments, obviously an important topic since it is from these refined instruments that nearly all of our modern knowledge has come. Following this are 119 pages on the nature of earthquake waves and the deductions from them. This statement gives some idea of the complexity of the record and the involved messages it brings from the earth's interior and which are still far from being completely understood. The last part of the book discusses earthquake distribution and seaquakes. J. B.

6. *Minerals of Japan;* by TSUNASHIRO WADA, translated by TAKUDZI OGAWA. Pp. 144 with thirty plates. Tokyo, 1904.—Notwithstanding the comparatively limited extent of Japan and the fact that its resources are as yet only partially developed, the country has afforded a large number of mineral species, many of them of peculiar interest either because of their rarity or of the beauty of their crystallization. The volume before us gives an excellent summary of this subject and deserves careful study by all interested. Concise accounts of the species identified are given, with exact statement of locality and numerous analyses; a series

of fine heliotype plates give representations of notable specimens, for example, of the well known quartz twins, also the fine stibnite and topaz crystals. Among other Japanese minerals of especial interest may be mentioned crystallized danburite containing a considerable amount of magnesia (7·67 p. c.); datolite at Nobori, Hyuga Pr.; chalcopyrite of varied and unusual habit; axinite, etc. A new species, *naëgite*, is also described, as noted below.

7. *Brief notice of some recently described Minerals*—NAËGITE is a new silicate of uranium and thorium collected with fergusonite from the placer tin washings near Takayama, Mino province; it is described by T. Wada on p. 49 of the Minerals of Japan (1904, see above). It occurs in small spheroidal aggregates, also rarely in small crystals of pseudo-dodecahedral habit; these are probably tetragonal and isomorphous with zircon. The color varies between dark pistachio-green, greenish gray and brown or reddish brown; under the microscope it is transparent, grass-green and highly refractive, though also often nearly isotropic. The hardness is about 7·5 and the specific gravity 4·09; it has marked radio-activity. An analysis by T. Tamura afforded:

| $SiO_2$ | $UO_2$ | $ThO_2$ | $Ta_2O_5$ | $Nb_2O_5$ | $CeO_2$ | $Fe_2O_3$ | CaO | MgO | $H_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| 34·89 | 28·27 | 16·50 | 7·00 | 4·10 | 1·59 | 1·60 | 1·71 | 0·57 | 3·12 = 99·35 |

The name is from the locality where the new mineral has been found, viz. Naëgi near Takayama.

TEALLITE is a new sulpho-stannate of lead from Bolivia, exact locality unknown; it is described by G. T. Prior. It occurs in thin inelastic, flexible and cleavable folia showing crystals face on the edges; the angles afforded by these proved that the mineral is orthorhombic and somewhat related in form to nagyagite. The hardness is 1 to 2 and the specific gravity 6·36; luster metallic, color blackish gray, streak black. The mean of two analyses gave: S 16·29, Sn 30·39, Pb 52·98, Fe 0·20 = 99·86. This yields the simple formula $PbSnS_2$ or $PbS.SnS_2$. Teallite is named after Dr. J. J. Harris Teall, Director-General of the Geological Survey of Great Britain and Ireland.

The same author has also analyzed carefully selected samples of franckeite and cylindrite, both from Poopó, Bolivia, the locality from which teallite may also very probably have been derived. The result is to give for franckeite the formula $Pb_5FeSn_3Sb_2S_{14}$ or $3\,PbSnS_2 . Pb_2FeSb_2S_5$; for cylindrite, $Pb_3FeSn_4Sb_2S_{14}$, or $3\,PbSnS_2 . SnFeSb_2S_5$. *Min. Mag.*, xiv, pp. 21–27, Oct. 1904.

PALMERITE is a new hydrated phosphate of aluminium and potassium described by Eugenio Casoria from a deposit of guano found in a large cavern at Monte Alburus near Controne, province of Salerno, Italy. It occurs in a white, amorphous pulverulent form, unctuous to the touch and resembling purified kaolin. An analysis yielded:

| $P_2O_5$ | $Al_2O_3$ | $K_2O$ | $Na_2O$ | $H_2O(100°)$ | ign. | $Fe_2O_3$ | $NH_3$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|
| 37·10 | 22·89 | 8·04 | 00·3 | 7·87 | 21·29 | 1·17 | 0·61 | 0·37 = 99·37 |

The calculated formula is $HK_2Al_2(PO_4)_3 + 7H_2O$. *Att. Accad. Georgofilè* (5), i, July 3, 1904.

## III. Miscellaneous Scientific Intelligence.

1. *Annual Report of the Regents of the Smithsonian Institution*, S. P. Langley, Secretary, *showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1903.* Pp. lxi, 376 with 124 plates. Washington, 1904.—This volume contains the usual account of the administrative activity of the Smithsonian Institution in its different directions. The work in one of these in particular, the International Exchange Service, is presented in a very interesting form. In an Appendix a striking exhibit is made of the extent to which this service has been developed; upwards of 150,000 packages were sent out to all parts of the world between July, 1902, and June, 1903, this work having nearly doubled in six years. The value of this service to the science of the country can hardly be overestimated. Another Appendix describes the additions to the National Zoological Park, with some interesting illustrations; still another gives a report of the work of the Astrophysical Observatory for the year ending June 30, 1903. It is interesting to note here that the bolographic work carried on showed the earth's atmosphere to have been more opaque than usual, the direct solar radiation having been reduced about 10 per cent on an average through the entire spectrum. It is also shown to be probable that the radiation has been decreased outside of the earth's atmosphere. A new determination of the temperature of the sun, based upon the distribution of the solar radiation in the spectrum, has yielded the result of 5,290° Centigrade above the absolute zero. As usual, the larger part of the volume of about 800 pages is given to the republication of a well-chosen series of scientific papers, showing the progress made in all departments of science. These are fully illustrated and form a most interesting series, which ought to be accessible to all intelligent people.

2. *Bulletin of the Bureau of Standards;* S. W. Stratton, Director. Vol. I, No. 1, pp. 124. Washington, 1904 (Department of Commerce and Labor).—The Bureau of Standards, established some four years since, in addition to its regular testing work, the value of which is now thoroughly appreciated in the country, has recently undertaken the publication of occasional Bulletins. These will contain the results of investigations and researches carried on in connection with the Bureau, and which are likely to be of general interest in the country, either on the scientific or technical side. The Bulletins will be issued as often as they are required to present papers which are ready for publication. The first number, issued November 1st, contains eight articles. L. A. Fischer discusses a recomparison of the United States prototype meter; K. E. Guthe gives a study of the silver voltameter, and also describes fibers resembling quartz made from asbestos (amphibole) and steatite; F. A. Wolff discusses the so-called international electrical units; P. G. Nutting has papers on the spectra of mixed gases, on secondary spectra, and

on new rectifying effects in conducting gases; C. W. Waidner and G. K. Burgess give results of determinations of the temperature of the arc varying from 3690° to 3720° C., according to the form of pyrometer employed.

3. *National Academy of Sciences.*—The autumn meeting of the National Academy was held in the buildings of Columbia University, New York city, on November 15 and 16. The following is a list of papers presented:

W. K. BROOKS: On the affinities of the Pelagic Tunicates.

W. K. BROOKS and S. RITTENHOUSE: The life history of *Turritopsis.*

W. K. BROOKS and R. P. COWLES: *Phoronis architecta*, its anatomy, life history, and branching habits.

JOHN TROWBRIDGE: On the electrical resistance of a vacuum.

FRANZ BOAS: Psychic associations in primitive culture.

M. I. PUPIN: Time electrical impulses.

C. BARUS: The occurrence of maxima and minima of atmospheric nucleation in approximate coincidence with the winter and summer solstices respectively.

L. A. BAUER: The system of magnetic forces causing the secular variation of the earth's magnetism.

R. H. CHITTENDEN: The influence of low proteid metabolism on the formation and excretion of uric acid in man.

EDWARD M. MORLEY: Note on the theory of experiments to detect the second power of the aberration of light. Also, Report of a repetition of the Michelson-Morley experiment on the drift of the earth through the luminiferous ether.

C. S. PEIRCE: On topical geometry.

N. YATSU: An experimental demonstration of the formation of centrosomes *de novo.*

T. H. MORGAN: An analysis of the phenomena of organic polarity.

E. B. WILSON: Experiments on prelocalization in the annelid ovum.

C. E. MENDENHALL: The absolute value of the acceleration of gravity determined by the ring-pendulum method.

R. S. WOODWARD: The double suspension pendulum for measuring the acceleration of gravity.

THEO. HOLM: The genus Claytonia,—morphological and anatomical studies.

CHARLES S. HASTINGS: A determination of the dispersive power of the human eye.

CHAS. F. CHANDLER: The air in the Subway in New York.

W. H. DALL: Biographical memoir of Charles Emerson Beecher.

EDGAR F. SMITH: Biographical memoir of Robert E. Rogers.

4. *American Association for the Advancement of Science.*—The fifty-fourth annual meeting of the American Association was held in Philadelphia, in the buildings of the University of Pennsylvania, during the week from Dec. 27 to 31. The various affiliated societies also held their meetings at the same time and place. This is the third "Convocation week" that has been observed at this season of the year.

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